THE PROVINCE OF ALBERTA

OIL AND GAS

CONSERVATION BOARD

A Description and Reserve Estimate

of

THE OIL SANDS OF ALBERTA

October, 1963

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October 1963

A B S T R A C T

On the basis of a study involving the nonconfidential data associated with over 1200 oil sands evaluation holes and 600 wells, the Board describes the oil sands deposits of northern Alberta and presents its estimate of the reserves that they contain.

The oil sands deposits are classified into three main groups that are distinguished from each other by the stratigraphic unit and the area in which they occur. The Athabasca deposit occurs almost entirely within the Wabiskaw-McMurray unit and is located in the northeastern part of Alberta; the Bluesky-Gething deposits exist in the Bluesky and Gething formations and are situated in the northwestern part of the Province, and the Grand Rapids deposits occupy portions of the Grand Rapids formation and are located in the central part of northern Alberta.

The evaluated portion of the Athabasca deposit occupies about five and three-quarter million acres and is buried by 0 to 2000 feet of overburden. The evaluated portions of the other two groups of deposits together cover over two million acres in area and are buried by between 500 and 2500 feet of overburden.

The oil content of the deposits varies laterally owing to pronounced variations in both the gross thickness of the deposit and the degree to which the oil sands are saturated.

Thickness variations are caused by irregularities in the relief of the underlying Paleozoic surface and by the lateral transition of the upper or lower oil sands to shale or water-bearing sand. Saturation variations are caused by changes in the ratio of interbedded shale partings to oil sand and changes in the texture of the oil sand.

Reserves have been estimated for the oil sands that, in the opinion of the Board, warrant an evaluation on the basis of the magnitude of the reserves and the adequacy of the data. The majority of the reserves in place were estimated by deriving oil pay values for each hole or well, plotting the values on maps, connecting the values by isopachs and measuring the reserve volume by means of a planimeter. Intervals having a weight saturation of less than two per cent were excluded from the estimate.

Recovery factors were selected by the Board to convert reserves in place to recoverable reserves of raw oil-sand oil and recoverable reserves of upgraded synthetic crude oil.

The following estimates are listed in terms of reserves in place, recoverable reserves of raw oil-sand oil and recoverable reserves of upgraded synthetic crude oil, respectively, for the deposit or group of deposits designated: Athabasca deposit: 626, 369 and 267 billion barrels; Bluesky-Gething deposits: 51, 28 and 21 billion barrels and Grand Rapids deposits: 33, 18 and 13 billion barrels. The Athabasca reserves

are further classified into overburden, oil saturation and drilling definition categories. The Bluesky-Gething and Grand Rapids reserves are classified by individual deposit and then further classified into overburden and drilling definition categories.

The Board believes that its estimate of the grand total of the oil sands reserves is in reasonable agreement with the actual total reserves in existence within the areas evaluated but it believes that a considerable amount of additional evaluation drilling is needed to establish, with confidence, the magnitude of the reserves within certain widespread portions of these areas. Furthermore, the Board expects that future evaluation drilling undertaken beyond the evaluated areas will warrant an increase to its present reserve estimate.

P R E F A C E

In the first section of this report, the oil sands deposits of Alberta are described with reference to their location, stratigraphic position, geology, depth of burial and oil content. In the second section, the Board classifies the oil sands reserves, describes the methods and factors used to estimate the reserves, presents its estimates of the reserves of each deposit and discusses the reliability of its estimates.

This report is based mainly on an oil sands study completed by the staff of the Board, although a number of oil sands publications and several submissions made to the Board at public hearings were considered when preparing certain parts of the report. The study covered an area extending across the Province between Townships 75 and 105 and it involved the examination of the logs and core analyses available for over 1200 evaluation holes and the logs and sample cuttings taken at approximately 600 wells. The majority of the evaluation hole data used for this study was supplied to the Board during the past five or six years pursuant to regulations issued under The Mines and Minerals Act and all of the data used for the study has been released by the Board for public examination in accordance with a policy established on November 24, 1952, by the Department of Mines and Minerals. The well data were supplied to the Board and subsequently released in compliance with the Drilling and Production Regulations issued under The

Oil and Gas Conservation Act.

The oil sands referred to in this report are primarily distinguished from the other oil-bearing sands of the Province by the type of crude oil they contain. In The Oil and Gas Conservation Act, the oil sands are defined as those having a "highly viscous crude hydrocarbon material not recoverable in its natural state through a well by ordinary production methods". The oil-sands oil is of a naphthene base, black in colour and contains a characteristically high percentage of sulphur, nitrogen and trace metals. Relative to the conventionally-produced crude oils of the Province, it is heavy, having a gravity that varies considerably but which, over the Athabasca deposit, averages about 10.5 degrees A.P.I. at 60^{o} Fahrenheit. The gravity of the oil in the Peace River area is similar to that of the Athabasca area but several minor deposits located some 100 miles northeast of the town of Peace River appear to have a lighter gravity oil and, therefore, they may not qualify under the oil sands definition of The Oil and Gas Conservation Act.

A Description and Reserve Estimate

of

THE OIL SANDS OF ALBERTA

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THE OIL SANDS OF ALBERTA

I. DESCRIPTION OF THE DEPOSITS

1. Identification

The Board has evaluatad the oil sands that occupy the shaded areas shown by Figure 1. These areas total approximately 8,000,000 acres and, therefore, underlie almost one-twentieth of the entire Province.

Between the shaded areas are extensive areas that may contain additional oil sands reserves. Data collected to date reveal the widespread existence of oil staining and low oil saturation and the local occurrence of medium and high saturation within these intervening areas, but the data are considered to be too inexact and incomplete to permit a detailed reserve evaluation of these areas.

The oil sands of Alberta occur within three distinct stratigraphic units of Lower Cretaceous age. Each unit is shown by Figure 2, a section that extends from a few miles west of the town of Peace River to several miles southeast of the town of McMurray, a distance of about 280 miles. The section intersects the three largest oil sands deposits of the Province. In the eastern part of the section, the Athabasca deposit is seen to occupy a major part of the Wabiskaw - McMurray stratigraphic unit. In the western part of the section, the Peace River deposit is noted to

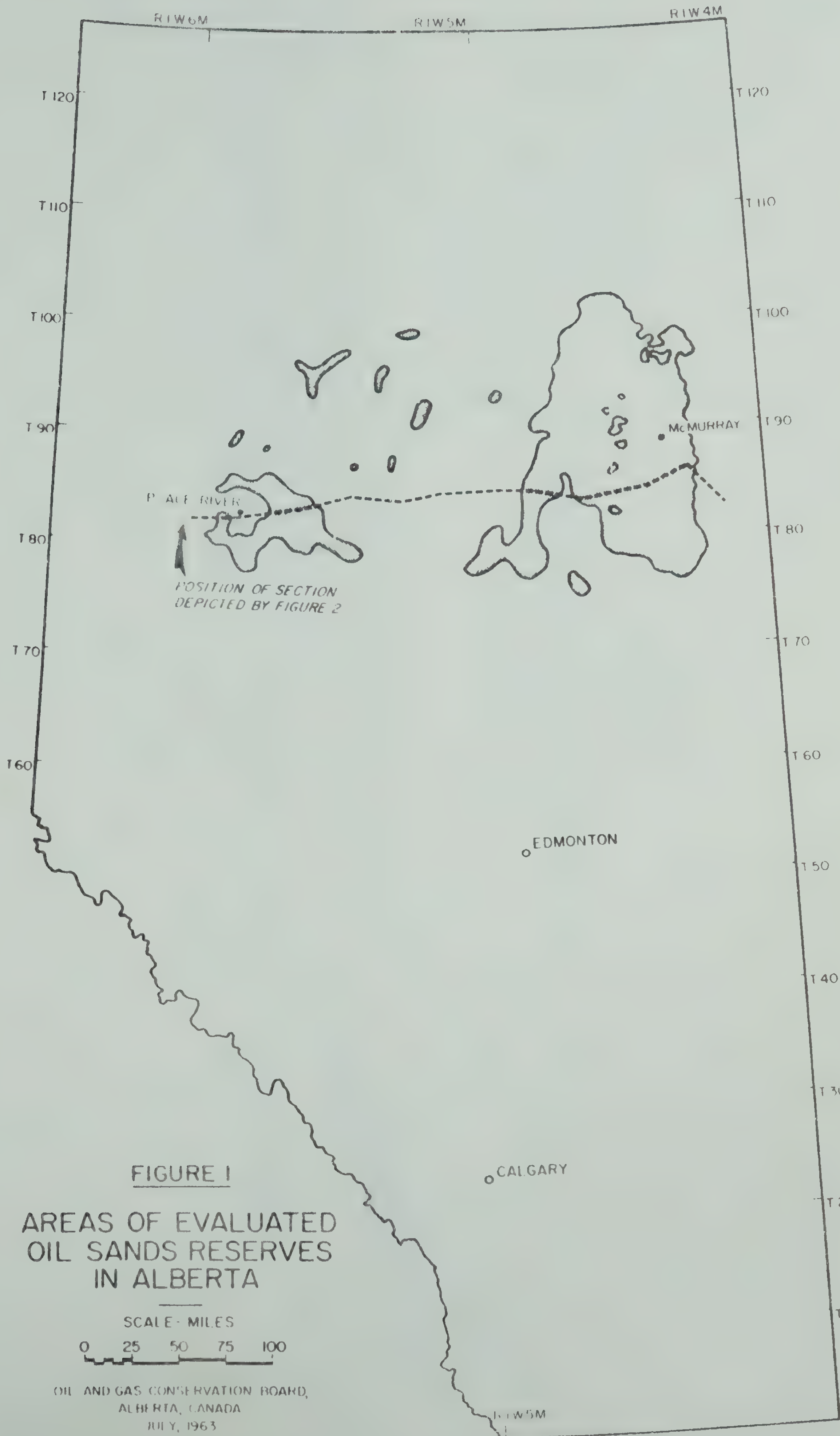


FIGURE I

AREAS OF EVALUATED OIL SANDS RESERVES IN ALBERTA

OIL AND GAS CONSERVATION BOARD,
ALBERTA, CANADA
JULY, 1963

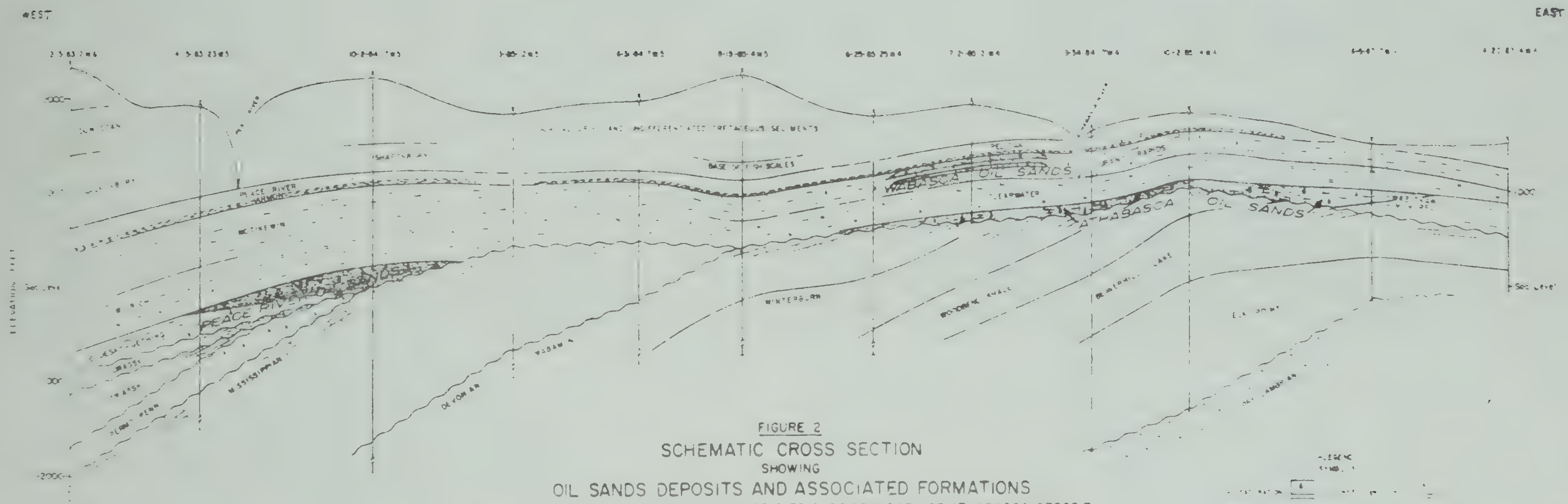
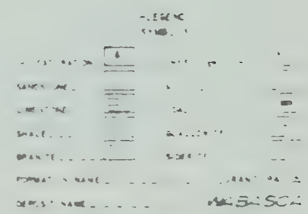


FIGURE 2
SCHEMATIC CROSS SECTION
SHOWING
OIL SANDS DEPOSITS AND ASSOCIATED FORMATIONS
WEST BOUNDARY OF PEACE RIVER DEPOSIT TO EAST BOUNDARY OF ATHABASCA DEPOSIT
(SEE FIGURE I FOR LOCATION OF CROSS SECTION)

HORIZONTAL SCALE MILES
0 5 10 20

OIL AND GAS CONSERVATION BOARD
JULY 1963



occur within the stratigraphically equivalent Bluesky-Gething unit. The Wabasca deposit overlies the western edge of the Athabasca deposit and occupies two sandstone members of the higher Grand Rapids formation. Other minor deposits, located north of the section, occur in the Bluesky-Gething and Grand Rapids units.

The evaluated oil sands deposits are separately designated by name and formation in Figure 3. This map corresponds to Figure 1 in that it shows only those oil sands areas that have been evaluated by the Board. No reference is made on this map to the leaner, more localized or undelineated oil sands that may exist beyond the evaluated areas.

The enormous Athabasca deposit of the Wabiskaw-McMurray unit is shown in the eastern part of Figure 3. The evaluated portion of this deposit occupies an area in excess of five and three-quarter million acres and it contains about 88 per cent of the total evaluated oil sands reserves of the Province.

The second most important group of deposits, from the standpoint of reserves, is outlined in the western part of Figure 3. They have been collectively named the Bluesky-Gething deposits after the stratigraphic unit in which they occur. They constitute the Peace River deposit and the smaller Buffalo Head Hills and Loon River deposits. The

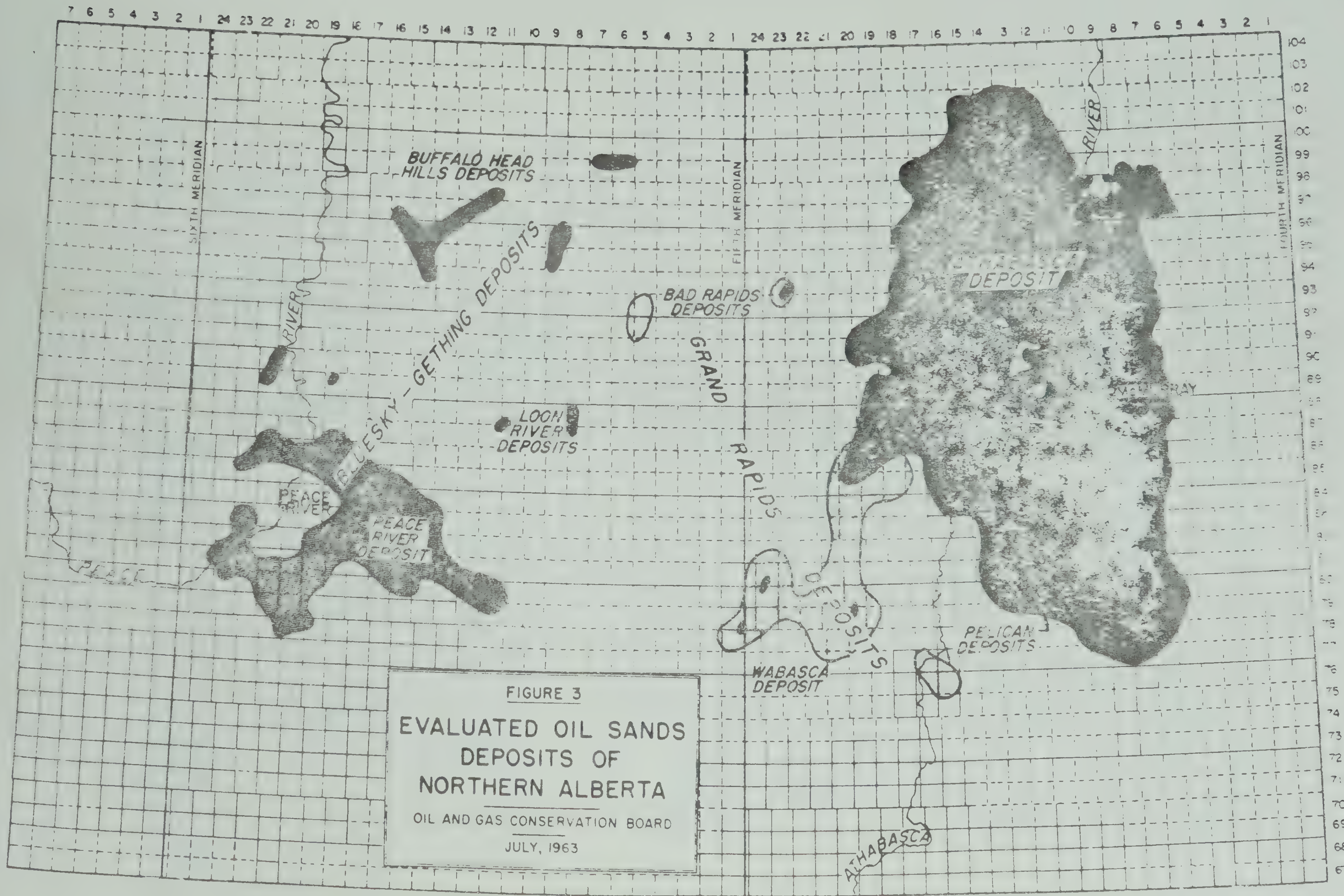


FIGURE 3

EVALUATED OIL SANDS DEPOSITS OF NORTHERN ALBERTA

OIL AND GAS CONSERVATION BOARD

JULY, 1963

evaluated portion of the Peace River deposit occupies an area in excess of one million acres and the latter two deposits occupy at least 150,000 acres. The Bluesky-Gething deposits contain about seven per cent of the total evaluated oil sands reserves of the Province.

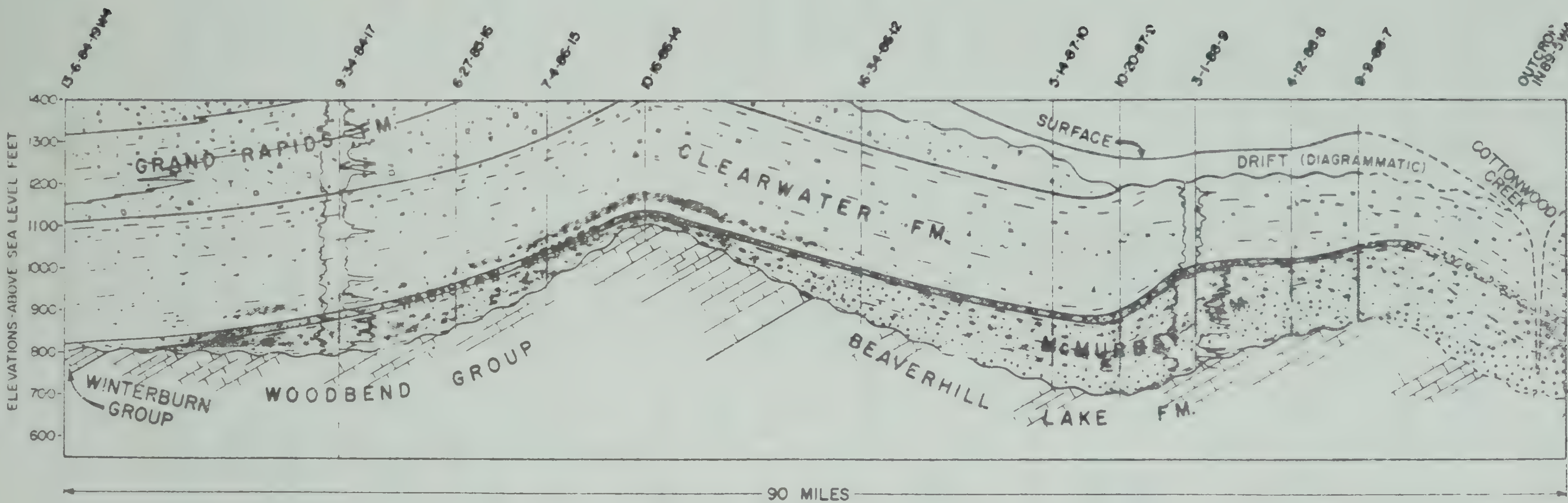
The remaining deposits, located in the central part of Figure 3, are collectively referred to as the Grand Rapids deposits, being so named after the formation in which they occur. They constitute the large Wabasca deposit together with the less significant Pelican and Bad Rapids deposits. The evaluated portion of these deposits occupy a total area of about one million acres and contain approximately five per cent of the presently known oil sands reserves.

2. Geology

(a) Athabasca Deposit

The Athabasca deposit occurs within the McMurray formation and the overlying Wabiskaw sandstone member of the Clearwater formation. Locally, it extends into a higher sand of the Clearwater formation. These two widespread Lower Cretaceous units underlie the shales of the Clearwater formation and overlie the eroded sediments of Paleozoic age.

Figure 4 is a southwest to northeast cross-section through the Athabasca deposit. It illustrates both the



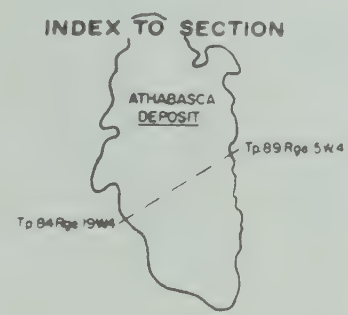
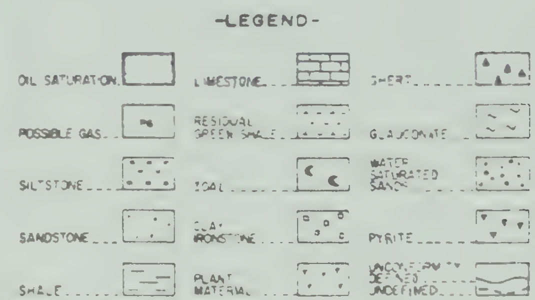


FIGURE 4

CROSS SECTION
THROUGH THE
ATHABASCA OIL SANDS DEPOSIT

OIL AND GAS CONSERVATION BOARD
ALBERTA, CANADA

JULY, 1963



relationship between the Wabiskaw and McMurray units and the relationship between these units and the other formations of the area. The section represents a distance of some 90 miles and the vertical scale has been exaggerated considerably so that stratigraphic details may be shown.

The Wabiskaw member, at its type locality in Township 78, Range 2, West of the Fifth Meridian, is 90 feet thick. However, its maximum thickness in the Athabasca deposit is shown by Figure 4 to be only about 30 feet. In parts of the deposit it is missing or difficult to distinguish from the McMurray formation. The Wabiskaw member consists of relatively continuous glauconitic and cherty quartz sandstones that were deposited under shallow marine conditions. The sandstones may contain a calcareous and clay matrix.

The McMurray formation is shown by Figure 4 to thicken in a north-easterly direction from its pinch-out edge to a maximum of over 200 feet. North of the section, it locally thickens to about 275 and 300 feet.

The McMurray formation has been subdivided by M. A. Carrigy of the Research Council of Alberta[1] into a relatively thin upper member, a thick and

widespread middle member and a sporadically developed lower member. The former two members consist mainly of medium to very fine pure quartz sands with lenticular interbeds of silts and shales. The upper member is generally horizontally bedded and contains limited brackish water fauna whereas the middle member commonly exhibits current and cross bedding and contains coal and plant remains. The lower member occupies the deeper depressions of the Paleozoic surface and contains lenticular beds of coarse grained and well rounded sand, silt and shale together with feldspar fragments and residual clay derived from the Paleozoic limestones.

No attempt has been made by the Board to determine whether the upper, middle and lower members, as defined by Carrigy in the vicinity of the Athabasca River, can be identified throughout the Athabasca deposit. However, some evidence in this regard was contained in a recent submission[(2)] made by the Shell Oil Company of Canada Limited to the Board. On the basis of similarities in the characteristics of the cores and logs taken at holes drilled in Township 95, Ranges 15 and 16, West of the Fourth Meridian, the Company divided the McMurray formation into the upper, middle and lower units, having average thicknesses of 20,

95 and 55 feet, respectively.

Studies have been completed by the Board to determine the nature and cause of the Wabiskaw-McMurray thickness variations exemplified by Figure 4. These variations and the actual thickness of the combined Wabiskaw-McMurray unit throughout the Athabasca deposit are shown in detail by the isopach map, Figure 5. The extreme variations in the shaded area of this map were found to have been caused mainly by the erosion of the McMurray formation during recent geological time. However, for the much larger and unshaded area, the thickness variations were generally found to be related to the relief of the underlying Paleozoic surface. To establish this relationship, Figure 6, a contour map showing the configuration of the Paleozoic surface, was prepared. By comparing Figures 5 and 6, it is concluded that the areas where the Wabiskaw-McMurray unit is abnormally thick correspond to the areas of low relief on the Paleozoic surface. Such areas are noticeable in Township 101, Range 12; Township 96, Range 13; Township 92, Range 18; Township 88, Ranges 15 and 16; Township 86, Range 8, and Township 81, Ranges 12 and 13. Conversely, a comparison between Figures 5 and 6 reveals that areas

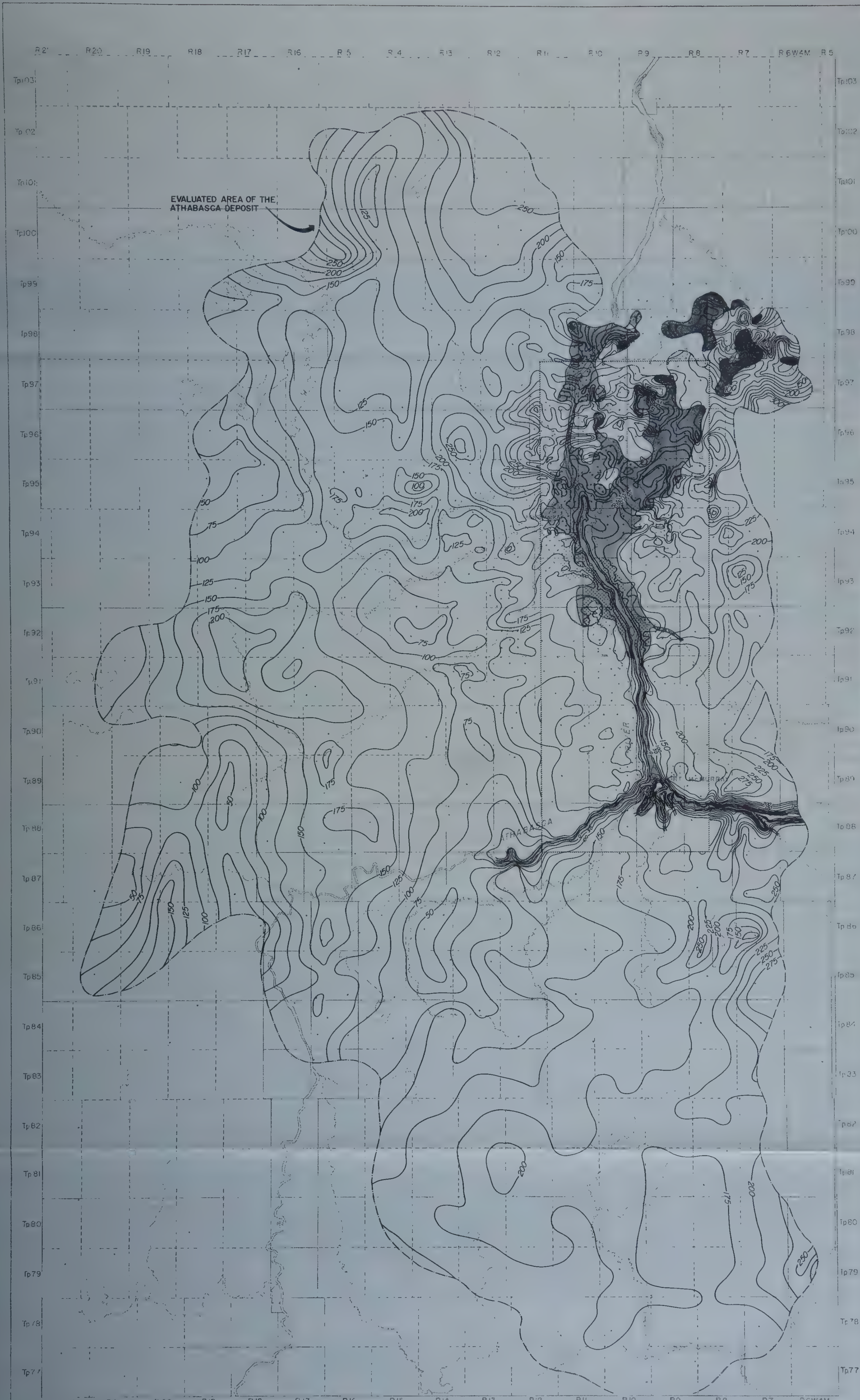


FIGURE 5

THICKNESS OF THE WABISKAW — McMURRAY UNIT THROUGHOUT THE ATHABASCA DEPOSIT

OIL AND GAS CONSERVATION BOARD, ALBERTA, CANADA

SCALE 0 5 10 20 30

POPULATION CENTER OR SETTLEMENT

OIL SANDS TEST HOLES OR WELLS

INDIVIDUAL LOCATION

AREA OF HIGH DRILLING DENSITY (Diagrammatic)

—LEGEND—

AREA WHERE SEDIMENTS PARTLY OR COMPLETELY ERODED

—NOTE—

1. The interval isopached constitutes sediments that are both barren and oil-bearing. It represents the gross interval in which the Athabasca Oil Sands occur, although locally saturation may extend into higher stray sands

2. Contour interval changed from 25 to 50 feet within the hatchured area

JULY, 1963

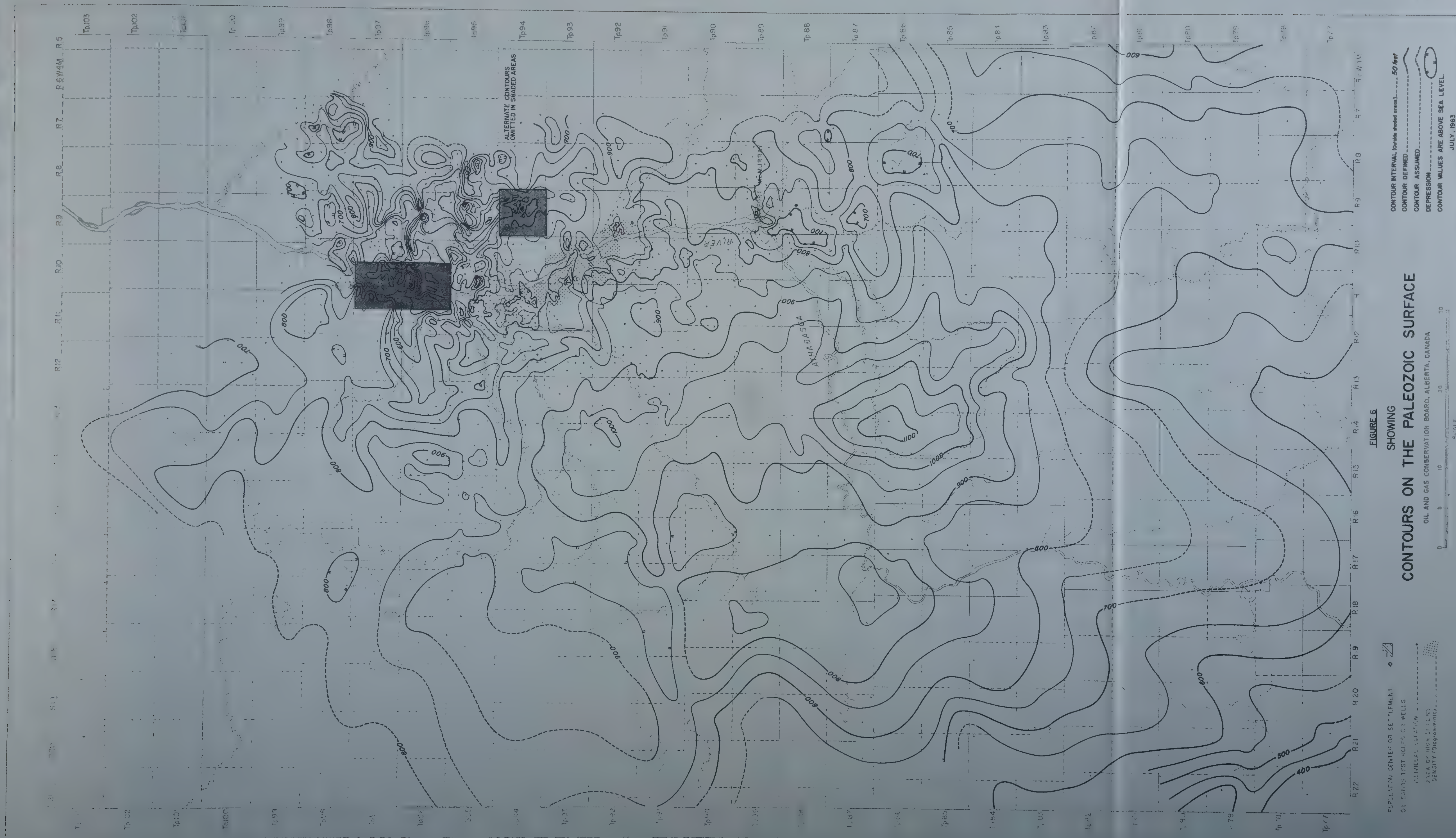


FIGURE 6
SHOWING
CONTOURS ON THE PALEOZOIC SURFACE

having abnormally thin sections of the Wabiskaw-McMurray unit correspond with areas of high Paleozoic relief. Examples of such areas are found in Township 92, Range 14; Township 90, Range 13; Township 89, Range 18; Township 86, Range 14, and Township 78, Range 10.

(b) Bluesky-Gething Deposits

West of the fifth meridian, oil saturation occurs within the Bluesky formation and the underlying Gething formation. The Bluesky and Gething formations, both of Lower Cretaceous age, are present throughout a considerable part of northwestern Alberta.

Figure 7 is a southwest to northeast cross section through the Peace River deposit. It indicates that, within the evaluated area of this deposit, the combined Bluesky-Gething unit thickens in a south-westerly direction from its pinch-out edge to a maximum thickness of approximately 300 feet. It also shows that the unit is overlain by shales of the Wilrich formation and that it lies unconformably on Jurassic and Mississippian formations.

Figure 8 is another cross section drawn through the Buffalo Head Hills and Loon River deposits. It indicates that the oil saturation in this area occupies a thin section of the Bluesky-Gething unit.

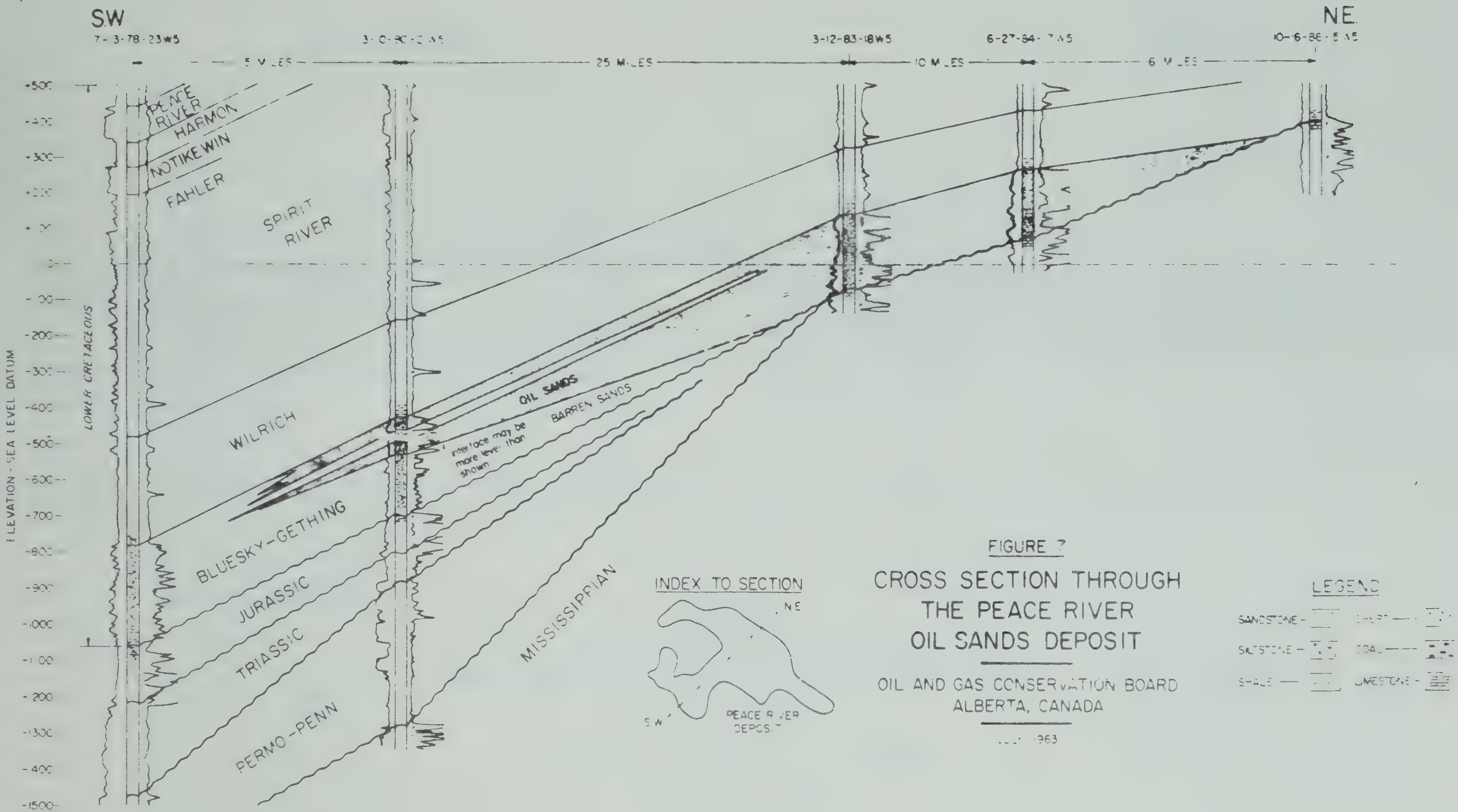
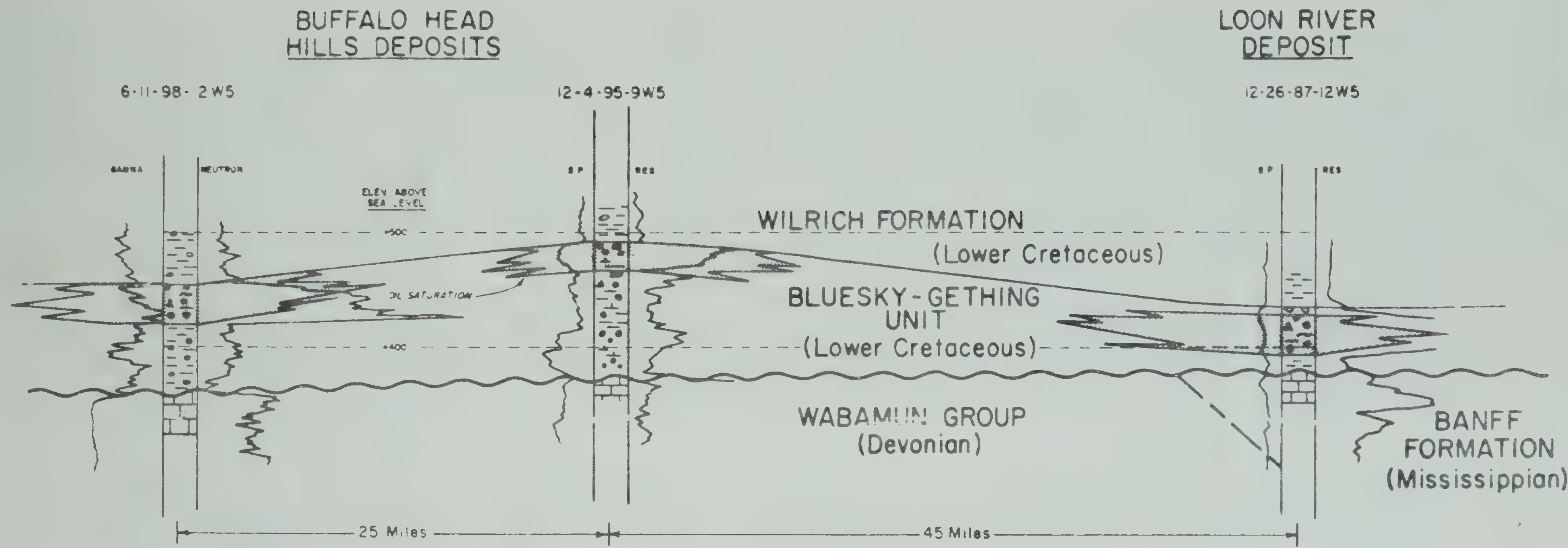


FIGURE 7

CROSS SECTION THROUGH THE PEACE RIVER OIL SANDS DEPOSIT

OIL AND GAS CONSERVATION BOARD
ALBERTA, CANADA

1963



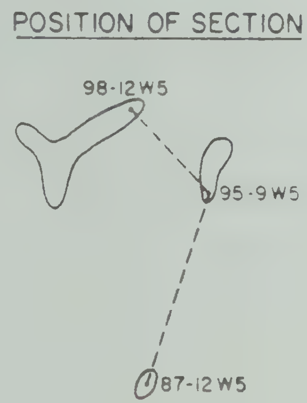


FIGURE 8

CROSS SECTION THROUGH
THE BUFFALO HEAD HILLS AND LOON RIVER
OIL SANDS DEPOSITS

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The latter is between 60 and 120 feet thick and lies on either Mississippian or Devonian formations.

In the area of the oil reserves, the Bluesky-Gething unit is composed mainly of sandstones and siltstones, shales and coal. The sand grains are mainly subangular and range in size from very fine (less than 100 microns) to very coarse (one millimeter or 1000 microns). Medium-sized grains of between 250 and 500 microns generally predominate. The sandstones may be glauconitic and fossiliferous and they may have a calcareous or clay matrix; in the lower part of the formation they contain minor amounts of pyrite, ironstone or carbonaceous material. In a few instances, large rounded chert grains of up to three millimeters in diameter were noted in the upper portion of the formation. The detrital zone, locally present at the base of the Gething formation, contains minor quantities of chert, dolomite and pyrite in the sand.

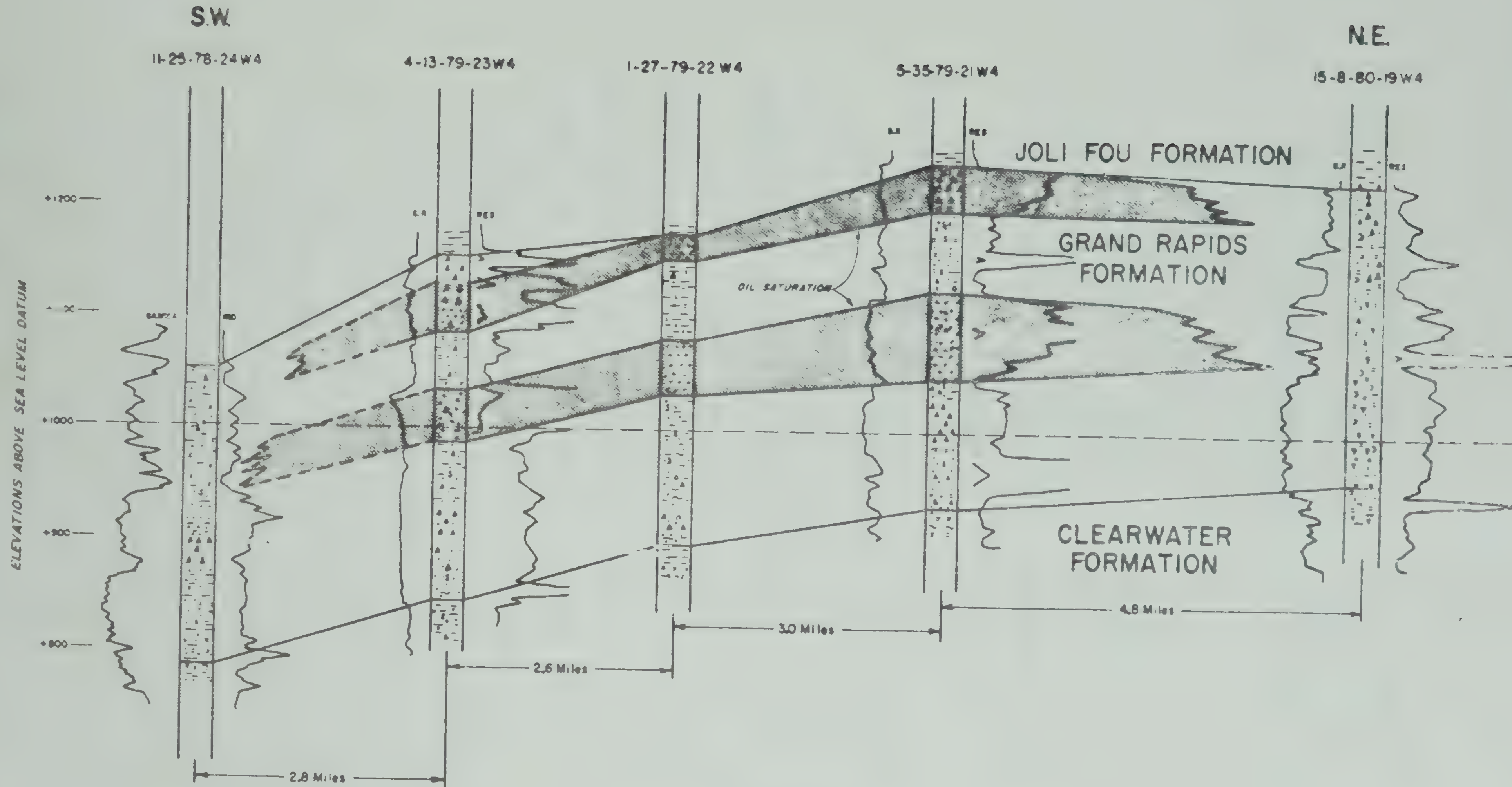
(c) <u>Grand Rapids Deposits</u>

The Grand Rapids formation, of Lower Cretaceous age, extends over a considerable portion of northern Alberta and has a maximum thickness of about 400 feet. It occurs between the overlying Joli Fou formation and the underlying Clearwater formation.

The components and lithology of the Grand Rapids formation are shown by Figure 9, a cross section through the Wabasca deposit. This section indicates that two relatively persistent oil-bearing sandstone members occur at the top and middle of the formation. Another more erratic sandstone development exists at the base of the formation.

The upper sandstone member is about 50 feet or less in thickness. It is oil-bearing throughout the evaluated areal extent of the Wabasca and Bad Rapids deposits and consists mainly of chert pebbles and quartz grains with a minor amount of clay, chlorite and mica. In the oil bearing area, the chert pebbles generally are medium to dark grey in colour, sub-rounded to well rounded and range from 1000 to 3000 microns in diameter. The quartz grains are generally sub angular and range in size from very fine sand (less than 100 microns) to medium-coarse sand (500 microns) with an intermediate (250 microns) size and, less commonly, the medium-coarse size predominating.

The middle sandstone member attains a maximum thickness of at least 75 feet. This sandstone is oil-bearing throughout the Wabasca and Pelican deposits where it consists mainly of quartz sand grains similar to those contained by the upper sand-stone member.



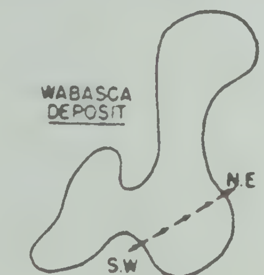


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FIGURE 9

CROSS SECTION
THROUGH THE
WABASCA OIL SANDS DEPOSIT

OIL AND GAS CONSERVATION BOARD
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LEGEND

SANDSTONE — SIDERITE —
SILTSTONE — GLAUCONITE —
SHALE — COAL —
CHERT — STRAY OIL STAINING OR SAT. —

The lower, less persistent, sandstone member occurs near the base of the Grand Rapids formation and is oil-bearing at one well in the Bad Rapids deposit and appears to be partially oil stained within the areal limits of the Wabasca deposit. Where it is oil-bearing, it is similar in lithology to the upper sand but may contain a lesser concentration of medium grey chert pebbles, more carbonaceous matter and perhaps some glauconite at the base.

3. Depth of Burial

Except for the localized outcrop areas associated with the Athabasca River and its tributaries, the evaluated oil sands areas of Alberta are covered by overburden.

The overburden generally consists of a thin layer of soil mantle and glacial drift together with the formations which occur between the drift and the oil sands. These formations, consisting mainly of soft sandstones, siltstones and shales, are shown and named in Figure 2. It is evident from Figure 2 that variations in the thickness of the overburden are caused by both variations in the structure or dip of the underlying oil sands and variations in the surface topography.

The thickness and configuration of the overburden covering the evaluated oil sands areas is described below for each of the three main groups of deposits.

(a) Athabasca Deposit

Figure 10 is an isopach map showing the thickness of the overburden covering the evaluated area of the Athabasca deposit. The isopach values represent the interval from surface to the highest occurrence of the oil sand having a saturation greater than 10 per cent by weight and, therefore, some leaner oil sands occur in the basal section of the overburden represented by the isopachs.

For the purpose of this map, the top of the 10 per cent oil sand was chosen as the base of the overburden because it generally appeared to represent the beginning of a relatively continuous interval of saturation, whereas the uppermost occurrence of the leaner sand more frequently appeared to be isolated from the main oil sands development. If the base of the overburden had been defined by the uppermost sands having a weight saturation of only five per cent, the overburden isopachs would be decreased by an average of less than 20 feet, although a few rare and isolated cases exist where they would be drecreased by 100 feet or more.

The overburden shown by Figure 10 is seen to be less than 100 feet in thickness in the vicinity of that part of the Athabasca River which is north of

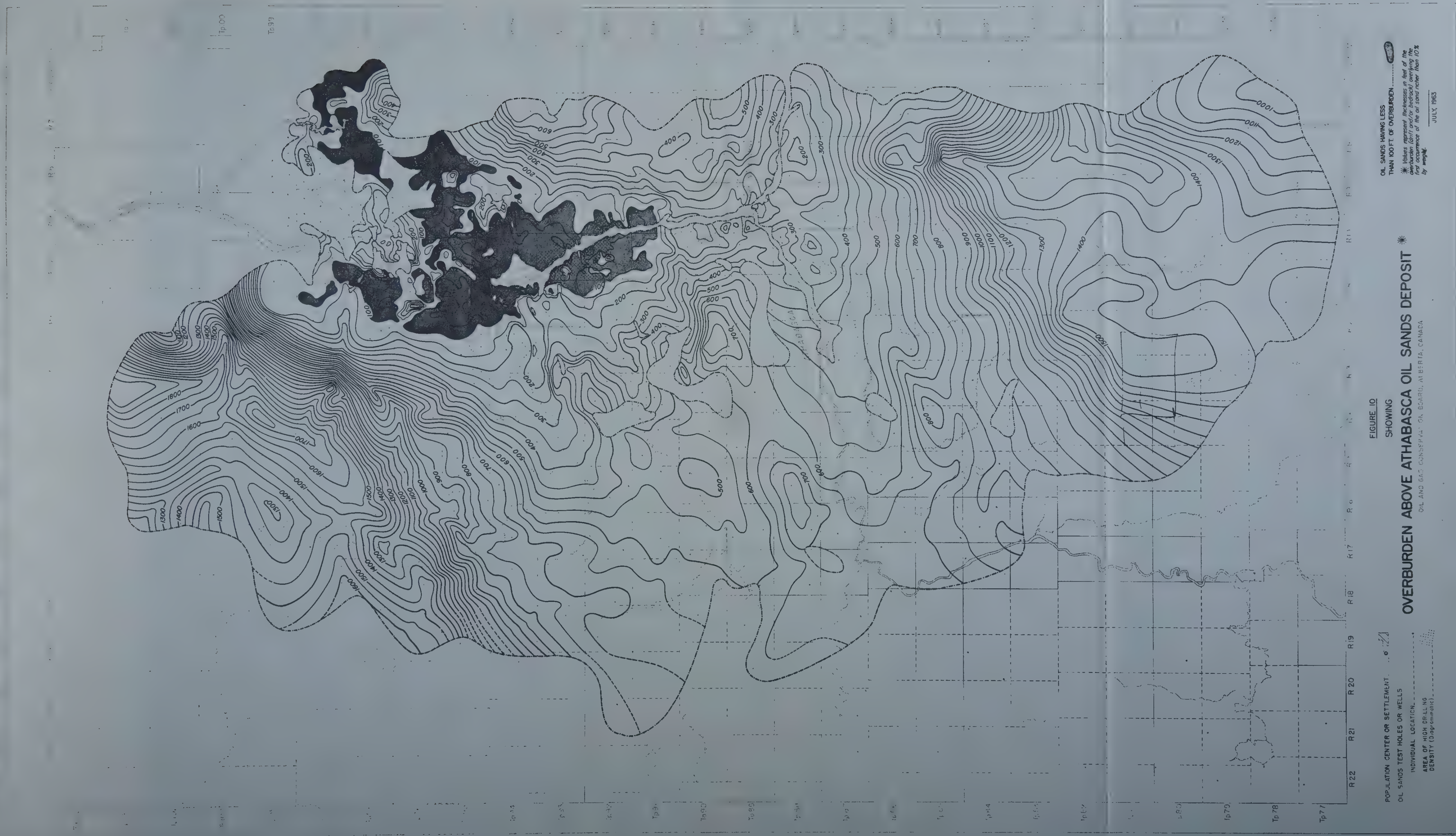

FIGURE 10

SHOWING

OVERBURDEN ABOVE ATHABASCA OIL SANDS DEPOSIT *

OIL AND GAS CONSERVATION BOARD, ALBERTA, CANADA

Township 90. From that area, the overburden abruptly thickens eastward to 600 feet, northward to 1,900 feet and westward to a maximum of 1,600 feet. Towards the south and particularly the southwest, the rate of overburden thickening is more gradual but maximum thicknesses of 1,500 and 700 feet, respectively, are attained in those directions.

(b) Bluesky-Gething Deposits

The isopachs and average values shown by Figure 11 are on a different basis than those of Figure 10 and represent the overburden that overlies the uppermost significant saturation of the Bluesky-Gething deposits. This basis was chosen because of the lack of detailed information on oil saturation in the Bluesky-Gething deposits.

The overburden covering the evaluated portion of the Peace River deposit is shown by the isopachs to increase in a westward direction from 1,500 to 2,300 feet and in a southward direction from 1,500 to 2,600 feet. The larger Buffalo Head Hills deposit is seen to be buried by between 1,100 and 2,100 feet of overburden and the smaller Buffalo Head Hills and Loon River deposits are noted to be covered by overburden that averages between 700 and 1600 feet in thickness.

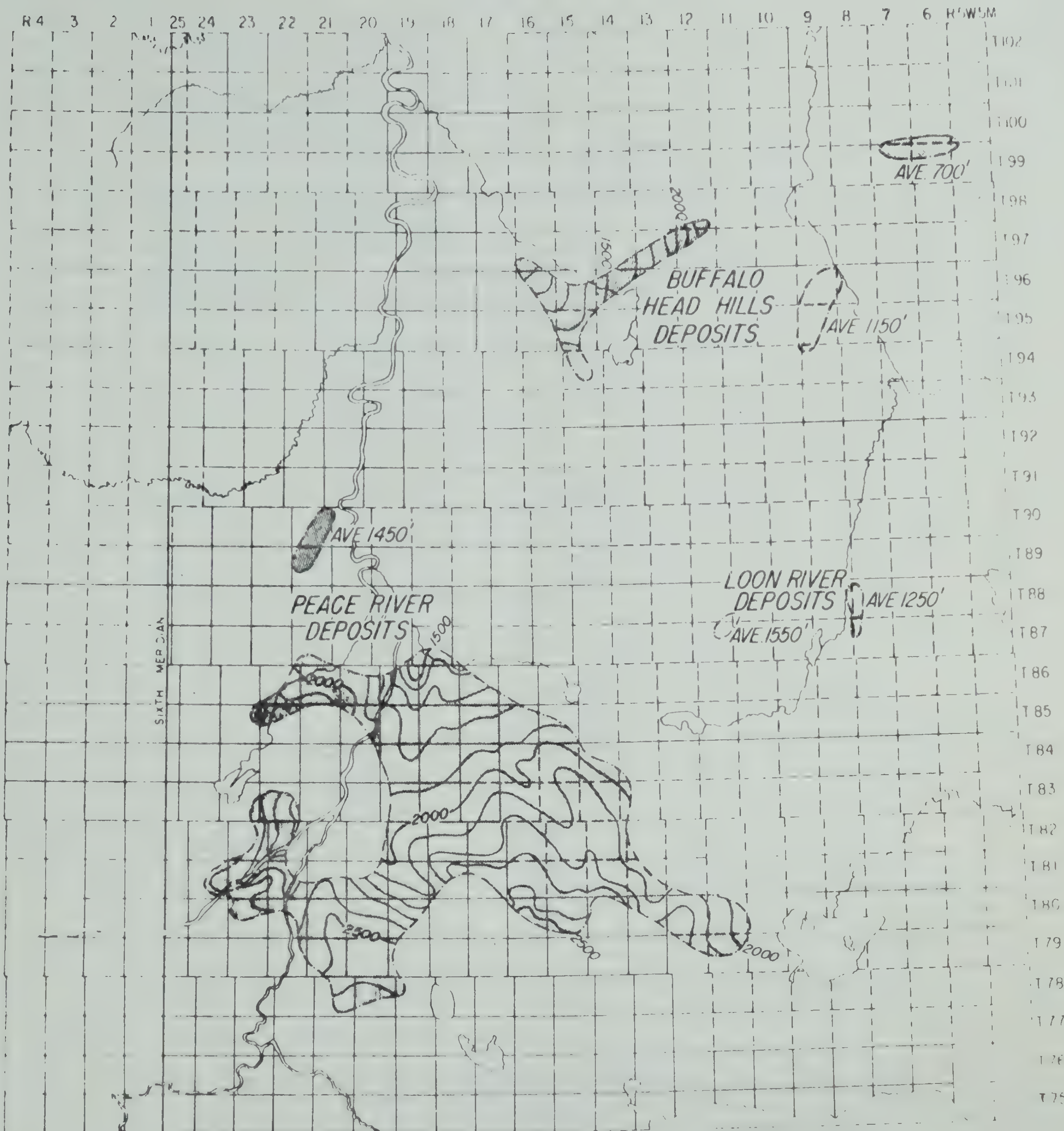

FIGURE 11

SHOWING

THICKNESS OF OVERBURDEN

ABOVE THE EVALUATED AREA OF THE

BLUESKY-GETHING OIL SANDS DEPOSITS

OIL AND GAS CONSERVATION BOARD
ALBERTA, CANADA
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(c) Grand Rapids Deposits

The thickness of the overburden covering the uppermost significant saturation of the Grand Rapids deposits is shown by Figure 12. This figure indicates that the overburden covering the large Wabasca deposit thickens in a southward direction from 300 to 1,100 feet. For the remaining smaller deposits, the overburden is expressed as a range between minimum and maximum values or, if the range is limited, as an average value. In this way, the figure indicates that the Bad Rapids deposits have from 500 to 1,100 feet of overburden and that the Pelican deposits have between 1,000 and 1,400 feet of overburden with an approximate minimum of 600 feet in the valley of the Athabasca River.

4. Oil Content

The oil content óf an oil sands deposit varies laterally due to variations in both the gross thickness of the deposit and the degree to which the oil sands are saturated. Each factor is discussed below.

(a) Variations in the Gross Thickness of a Deposit

Variations in the thickness of a deposit are caused by irregularities in the relief of the underlying Paleozoic surface. In a previous section of this report, Figure 2 indicated that the western part

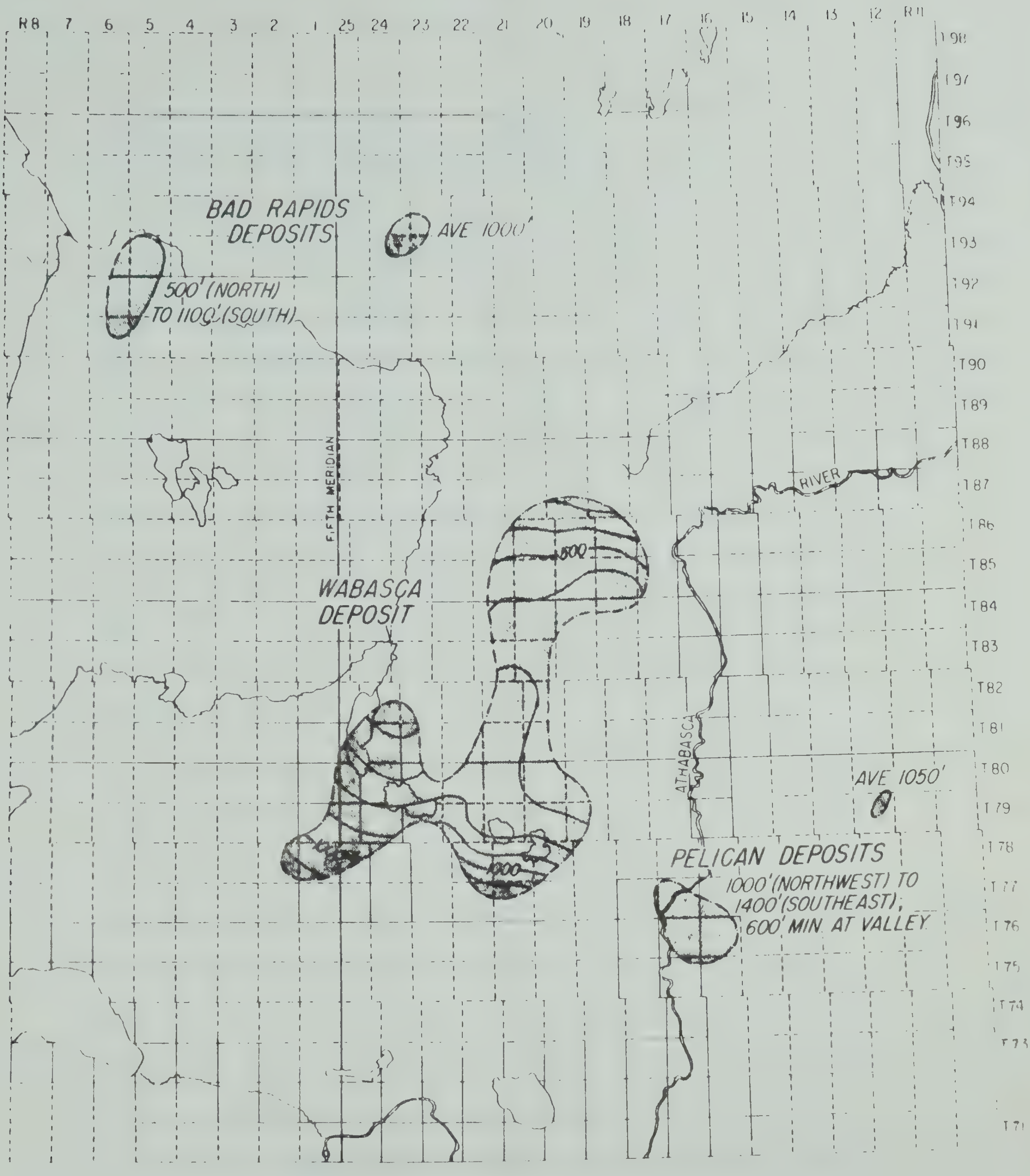


FIGURE 12

SHOWING

THICKNESS OF OVERBURDEN

ABOVE THE EVALUATED AREA OF THE

GRAND RAPIDS OIL SANDS DEPOSITS

OIL AND GAS CONSERVATION BOARD

ALBERTA, CANADA

JULY, 1963

of the Athabasca deposit and the eastern portion of the Peace River deposit thinned and finally pinched out owing to the ascending relief of the Paleozoic surface. In addition, Figure 4 indicated that a Paleozoic hill, about 40 miles in length, caused a regional reduction in the thickness of the Athabasca deposit. Less obvious are the local and abrupt thickness variations caused by the much smaller Paleozoic remnants within the areal limits of the Athabasca deposit. One such feature in Township 95, Range 11, was noted to cause a one-half reduction in the thickness of the deposit in a distance of less than one mile.

Variations in the thickness of a deposit are also caused by the lateral transition of the lower or upper oil sands to water-bearing sands or tight sandstone, siltstone or shale. Figure 2 indicates that the eastern portion of the Athabasca deposit and the western portion of the Peace River deposit thin and finally terminate owing to the transition from oil-bearing to water-bearing sands. Figure 4 illustrates that thinning occurs within the areal limits of the Athabasca deposit due to the lateral transition from oil-bearing sands to water-bearing sands or tight sandstone, siltstone or shale.

(b) Variations in Oil Saturations

Core analyses representing both the Athabasca and Peace River deposits indicate that the oil saturations are variable in magnitude, resulting in a heterogeneous distribution of the oil in the deposits. The saturations for successive one-foot intervals are commonly observed to vary from the maximum oil saturations of over 15 per cent by weight to the minimum saturations of less than one per cent. These variations are, for the main part, attributed to the sudden occurrence of shale partings in the intervals for which the lower oil saturations were measured. In addition, M. A. Carrigy[3] has established that variations in the saturation of oil sand samples are related to both the percentage of clay-size material in the sample and the median diameter of the sample.

As a result of saturation variations in the oil sands, the total oil content of the deposit has been observed to decrease by as much as two thirds or more over horizontal distances of only one-half a mile in spite of the fact that the thickness of the gross interval remained relatively uniform.

On the other hand, other oil sands areas exhibit relatively uniform oil saturations. For example, oil saturations have been observed to remain relatively constant over distances of about 10 miles in certain parts of the Athabasca deposit.

II. RESERVES

The Board has estimated the reserves of those oil sands that, in its opinion, warrant an evaluation on the basis of the magnitude of the reserves and the adequacy of the data. The areas for which the reserves have been estimated are outlined by Figure 3, a map referred to in the initial part of this report.

In this section, the Board describes its reserve classification system, outlines its evaluation methods, presents a tabulation of the reserves for the various deposits and discusses the reliability of the estimates.

1. Classification

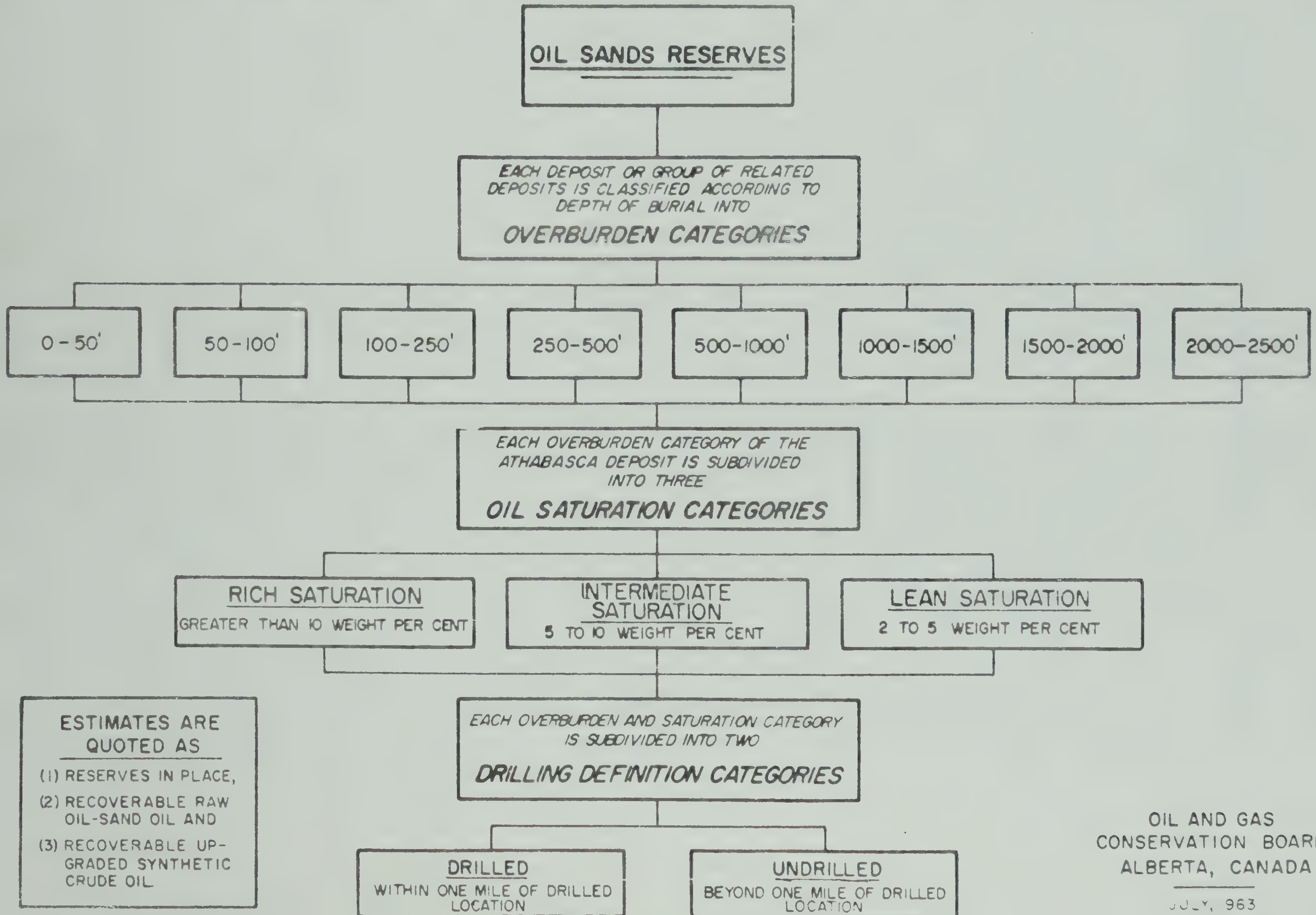
The Board has classified the oil sands reserves of each major deposit and each group of related minor deposits in the manner shown by Figure 13. This classification scheme is based upon three factors: the depth to which the reserves are buried, the extent to which the host sand is saturated and the degree to which the reserves have been defined by drilling. Each factor and the categories related to it are explained below.

(a) Depth of Burial

The reserves of each deposit have been grouped in terms of the following overburden categories, the limits of which were arbitrarily selected: 0 to 50 feet, 50 to 100 feet, 100 to 250 feet, 250 to 500 feet,

FIGURE 13

CLASSIFICATION OF OIL SANDS RESERVES



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500 to 1000 feet, 1000 to 1500 feet, 1500 to 2000 feet and 2000 to 2500 feet.

The oil sands areas represented by these overburden categories may be determined for each deposit by referring to the overburden maps designated as Figures 10, 11 and 12 in the foregoing part of this report. Although Figure 10 represents the interval of overburden from surface to the highest 10 weight per cent oil sand of the Athabasca deposit, all higher and leaner oil sands were considered for the reserve estimates. Furthermore, as previously mentioned, if the base of the overburden had been selected at, for example, the uppermost occurrence of the five weight per cent oil sand, the overburden values would be decreased by an average of less than 20 feet. Such a reduction would slightly increase the 0 to 50 - foot overburden area and decrease the 1500 to 2000 - foot area. The remaining areas would remain about the same in size but their position on the map would be slightly shifted in the direction of overburden thickening. Figures 11 and 12 represent the thickness of overburden occurring between surface and the highest significant oil saturation of the Bluesky-Gething and Grand Rapids deposits. As such, they represent the true interval overlying the section

for which the reserves were estimated.

(b) Oil Saturation

A classification based on the degree of saturation has been applied only to the reserves of the Athabasca deposit. It has not been applied to the reserves associated with the Bluesky-Gething or Grand Rapids deposits because the data available to the Board at the time of the study were considred to be too inadequate to warrant such a classification of these deposits.

The following three categories have been used to classify each overburden category of the Athabasca reserves: (1) rich sand category, associated with those sands having an oil saturation greater than 10 weight per cent (19.2 volume per cent); (2) intermediate sand category, associated with the sands having an oil saturation of between five and 10 weight per cent (9.9 and 19.2 volume per cent), and (3) lean sand category, representing the sands having a saturation of between two and five weight per cent (4 and 9.9 volume per cent). The limits of these three categories were selected in an arbitrary manner.

The oil sands representin the three saturation categories are intermixed throughout the Athabasca deposit and each category is commonly represented at

any drilled location. However, as shown by Figure 14, the percentage of the oil pay excluded by a given cut-off can vary at different localities. Curve A represents a cored section taken at a locality where the rich sands are absent. Some 32 and 66 per cent of the oil pay at this locality are contained by the lean and intermediate sands, respectively. Curve C represents a single locality at which all of the analysed pay is contained by the rich sands only. The cases represented by curves A and C are rare and they were chosen to show extreme limits between oil sands localities having only low saturations and those having only high saturations. Curve B represents the total oil pay derived by the Board from 480 core analyses of the Athabasca deposit. This pay is distributed among the saturation categories as follows: rich sand: 68.7 per cent; intermediate sand: 23.7 per cent, and lean sand: 6.5 per cent. In addition, some 1.2 per cent of the total oil pay has been excluded by the two per cent weight saturation cut-off used in this study.

Since the reserve estimates of the Bluesky-Gething and Grand Rapids deposits were based on a visual estimate of saturation, no definite minimum saturation cut-off can be cited as a basis for the

FIGURE 14

RELATIONSHIP BETWEEN OIL CONTENT AND SATURATION CUT-OFF, ATHABASCA DEPOSIT

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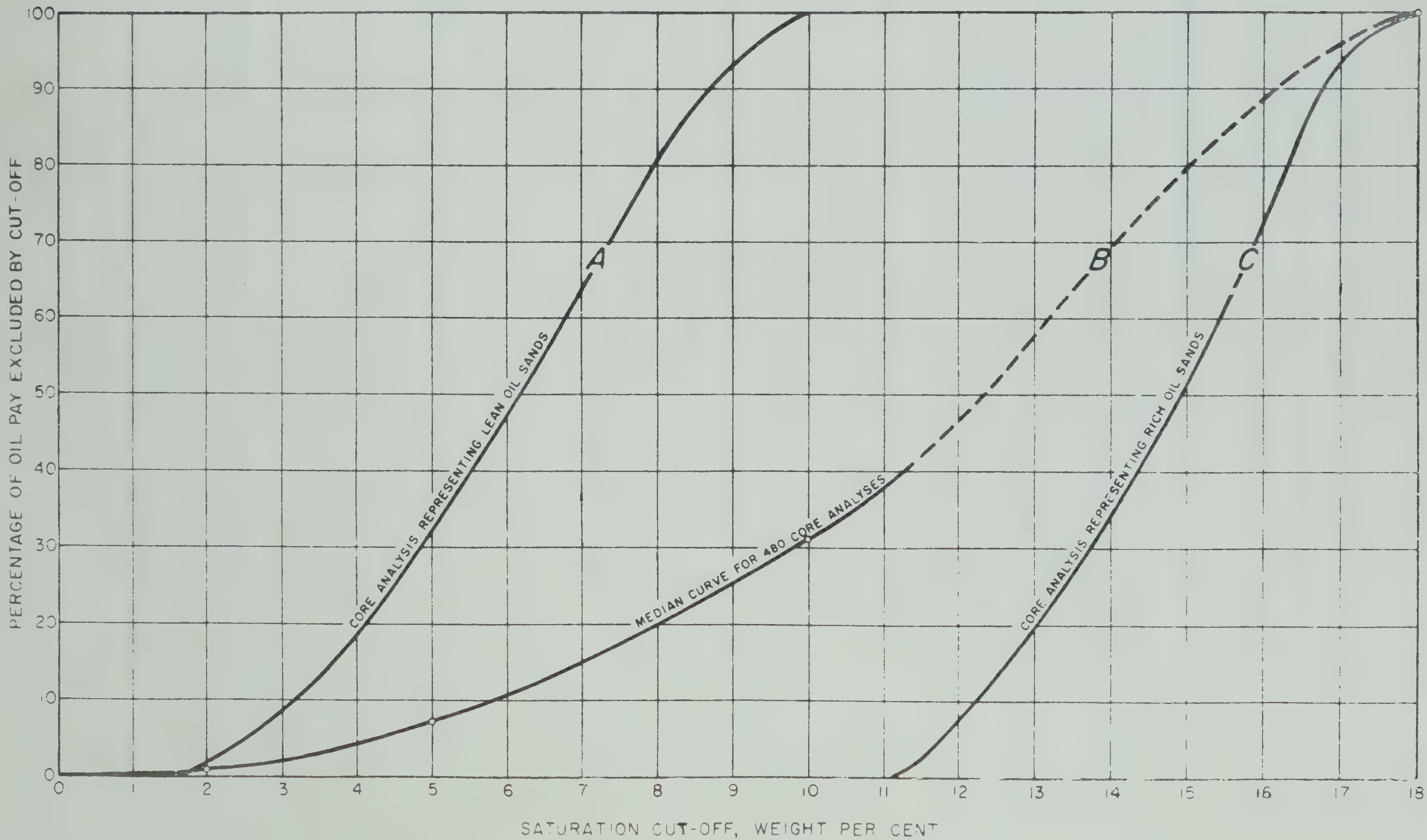


estimates. However, when the pay thicknesses were determined, attempts were made to exclude material that appeared to be below the lean sand category.

(c) Definition of Drilling

The reserves of each deposit have been further subdivided into the drilled and undrilled categories.

The drilled reserves are defined as those reserves situated within one mile of the evaluation hole or well on which they are based. For holes or wells separated by more than two miles, the area of the drilled reserves assigned to each drilled location was that of a circle having a radius of one mile. In cases where the holes or wells are separated by less than two miles or where unproductive acreage obviously occurred within a mile of the hole or well, the areas of the drilled reserves were adjusted accordingly.

The undrilled reserves constitute those reserves located beyond one mile from drilled locations. They are equal to the difference between the total reserves, as evaluated by isopachs, and the drilled reserves

The distance of one mile was selected on an arbitrary basis to distinguish between the drilled and undrilled categories. Generally, the total oil

content at a hole or well can be expected to remain relatively constant over a mile or even greater distances although a few examples have been noted where the total oil content undergoes a considerable change over distances of less than one mile.

2. Estimation Methods

Certain methods have been developed by the Board to estimate the reserves of the oil sands. These methods take into account the following factors peculiar to the oil sands or their evaluation data: (1) the spacing of the holes or wells at which the data was taken is haphazard and generally wide, (2) the core analyses usually express oil saturation in terms of a weight percentage rather than a volume percentage, (3) for certain widespread areas, the only records available to the Board to determine oil saturation consisted of sample cuttings and logs, (4) many electric logs were suitable only for qualitative, rather than quantitative, determinations and (5) the recovery of the oil-sand oil is dependent upon either mining or artificial stimulation techniques and not upon the natural drive applicable to conventional fields.

The following discussion concerning estimation methods is divided into two parts. Under the first heading is a summary of the approach taken to calculate

the reserves. Under the second heading is a description of the reserve factors and an explanation of the manner in which they were derived.

(a) General Approach

In the case of the rich and the intermediate sands of the Athabasca deposit, the "oil feet" * were separately derived from core analyses and logs, plotted on separate maps and the values were connected by isopachs to provide maps representing the volume of the rich and intermediate oil sands reserves in place. The overburden map was superimposed on each oil pay isopach map and the reserve volumes were determined by planimeter for each overburden category. Drilled reserves were calculated by multiplying the area situated within one mile of each drilled location by the appropriate pay values.

To estimate the reserves contained by the lean sands of the Athabasca deposit, some 480 core analyses were first processed to determine the ratio of core analysis oil pay contained by the lean oil sands category to the core analysis oil pay contained by the intermediate category. The reserves contained by the lean sands under a particular overburden category were then calculated by multiplying this

* "Oil feet" is defined as the product of oil sand thickness and volume fraction oil saturation.

ratio by the total reserves of the intermediate sands belonging to the same overburden category. Owing to the adoption of this short-cut method, no need arose to either calculate individual pay thicknesses or saturations or to prepare a reserve map for the lean oil sands.

The approach taken to estimate the reserves of the Bluesky-Gething and Grand Rapids deposits was similar to that taken for the rich and intermediate sands of the Athabasca deposit except that no attempt was made to classify the reserves on the basis of the saturation of the sand. Such a classification was avoided due to the inadequate quality of the data available for estimating the saturation of these deposits.

The final stage of the reserve calculations involved the conversion of reserves in place to recoverable reserves. For this purpose, the Board, having regard to evidence submitted to it at public oil sands hearings, selected a set of recovery factors which are explained in the following section of this report.

(b) Details of the Methods

The factors, procedures and calculations used to estimate the oil sands reserves are discussed in detail below.

(i) Weight to Volume Conversion Factor

The weight to volume conversion factor is the factor used to convert oil saturation from a weight percentage to a volume percentage of the oil sand. The factor has been applied to those core analyses that are expressed in terms of oil saturation by weight in order to derive the volume saturation factor necessary to estimate the reserves.

Cores representing some 10,000 feet of oil sand recovered from 200 evaluation holes drilled into the Athabasca deposit have been analysed in terms of both volume and weight percentage oil saturation. On the basis of these core analyses, the Board has calculated average conversion factors of 1.92 for the rich sands and 1.98 for the intermediate sands.

(ii) Oil Sands Saturation and Thickness

The oil sand saturation and thickness values were estimated on the basis of logs in combination with either core analyses or sample cuttings. The use of sample cuttings was confined to those deposits having limited or no core analysis coverage. Each of the two procedures is separately described below:

Core Analysis - Log Procedure

The core analysis-log procedure was applied to the Athabasca deposit for which some 1000 core analyses* and a similar number of logs associated with 1250 non confidential holes were examined.

For the intervals covered by core analyses, the oil pay was calculated directly from the oil sand saturation and thickness values recorded by the core analyses.

For the intervals that were not covered by core analyses, the oil sand thicknesses were calculated from logs and field average saturation factors were applied to these thicknesses.

Figure 15, part (i), illustrates the method used to calculate oil sand thicknesses from logs. The log resistivity cut-offs representing five and 10 per cent weight saturations were determined by calibrating logs against core analyses at the nearest cored holes. In some instances,

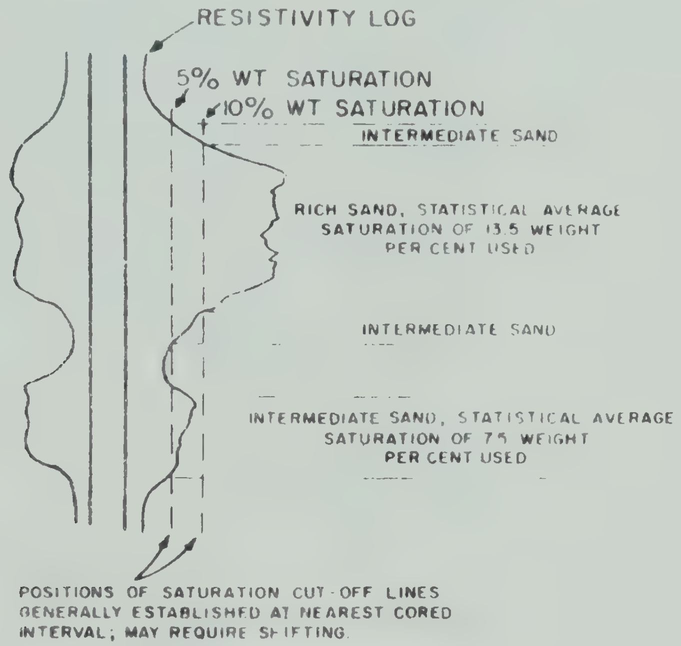
* Of this total, 450 represent localized lease blocks and have negligible impact on the total reserve estimate.

FIGURE 15

DETERMINATION OF THE SATURATION AND THICKNESS OF OIL SAND

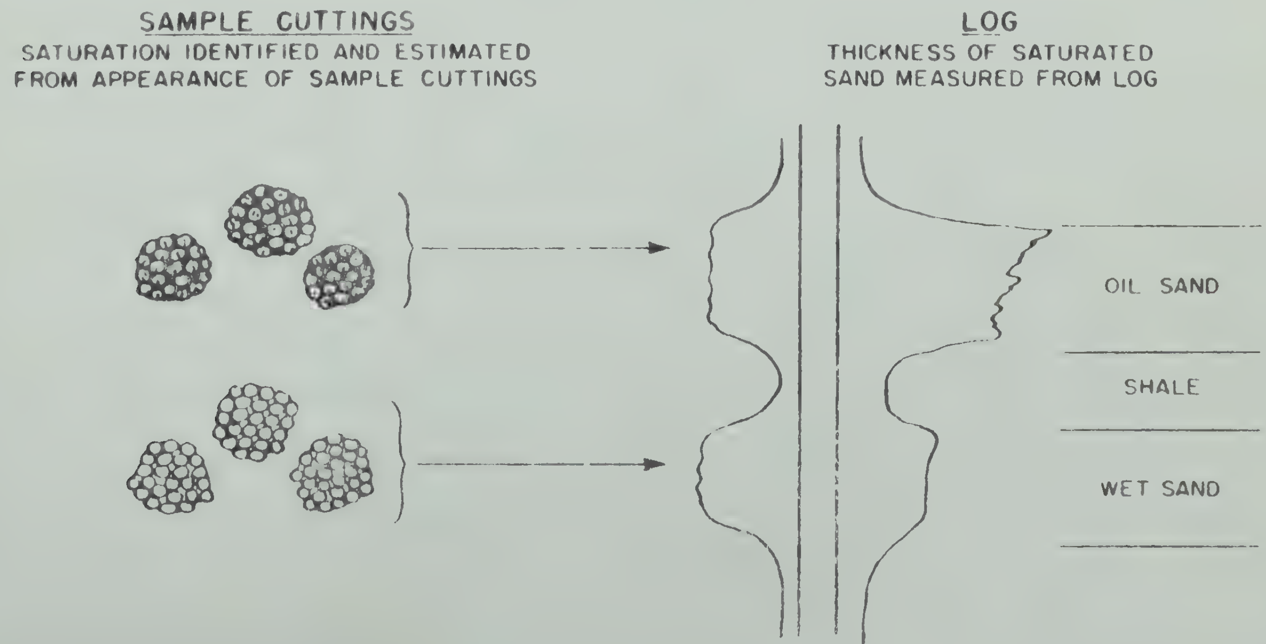
(I) USING LOGS CALIBRATED AGAINST CORE ANALYSES

(APPLICABLE TO THE UNCORED INTERVALS OF THE ATHABASCA DEPOSIT)



(II) USING SAMPLE CUTTINGS AND LOGS

(APPLICABLE TO THE GENERALLY UNCORED BLUESKY-GETHING AND GRAND RAPIDS DEPOSITS)



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the calibrations obviously did not apply to the log of the uncored hole and an arbitrary shift had to be applied. After drawing the resistivity cut-off lines, the oil sand thicknesses belonging to the rich and intermediate categories were separately totalled for each log and average saturation factors of 13.5 and 7.5 per cent by weight were applied to each total. These products, when multiplied by the appropriate conversion factors, provided the total oil feet belonging to each saturation category in the well.

To derive the average saturation factors, the staff of the Board processed some 500 core analyses representing 84,000 feet of oil sand in the Athabasca deposit. On this basis, footage weighted average saturation factors of 13.65 and 7.55 weight per cent were calculated for the rich and intermediate categories, respectively. It was then recognized that owing to the unequal areal distribution of the cored holes, a volume weighting factor should be applied. Footage weighted average saturation factors were then calculated for each township and the township values were arithmetically averaged. In this

way, volume weighted average saturation factors of 13.36 and 7.38 per cent were calculated. However, a complete volume weighting by townships was not considered realistic because some townships were each represented by several thousand feet of core, whereas others, particularly those near the fringe of the deposit, were represented by only a few feet of core. Therefore, upon concluding that the most appropriate field average factors would be between the two calculated sets of values, the Board selected average saturation values of 13.5 and 7.5 weight per cent as a basis for its reserve estimates.

Sample Cuttings - Log Procedure

This procedure is illustrated by Figure 15, part (ii). It was applied to the Bluesky-Gething and Grand Rapids deposits because impregnated sample cuttings were available and non confidential core analyses were not available for the major part of these deposits.

According to this procedure, an interval of sand could contribute to the reserve estimate if, firstly, the sample cuttings appeared to have an oil content in excess of

about two per cent weight saturation and, secondly, the logs appeared to represent oil-bearing sand.

The oil saturation values were estimated from the appearance of the sample cuttings as seen through a binocular microscope. To improve the accuracy of estimating oil saturations in this way, comparisons were made between the saturation measurements and the appearance of certain analysed oil sands cores. In this way, a relatively reliable method was developed for estimating oil saturation values from the appearance of the sample cuttings.

In recognizing the hazard of estimating oil saturations in this way, the Board attempted to be conservative in estimating the saturation values. The maximum oil saturations were restricted to a weight saturation value of 10 per cent for the Peace River deposit and only five per cent for the Buffalo Head Hills and Loon River deposits, the lower value reflecting the lighter staining observed for the latter deposits. However, for the Grand Rapids

deposits, a slightly less conservative ceiling of 12 per cent was applied to those sands that appeared to be completely saturated. A maximum weight saturation of 17 or 18 per cent is theoretically possible for the oil sands of both formations.

Saturation values were not derived from the quantitative interpretation of the logs. This technique was avoided for two reasons. Firstly, the conglomerate and fresh water content of the Gething formation cause resistivity log characteristics that correspond to the log characteristics of the oil sand. Secondly, both formations lack a sufficient number of core analyses to enable a reliable calibration of the logs for saturation calculations.

When oil saturation was identified, logs, rather than sample cuttings, were used to derive the thickness of the sands to which the oil saturation factor could be applied. Sample cuttings were not used to determine the thickness of the oil sand since they are subject to contamination and inaccuracies in the measurement and recording of depth.

(iii) Oil-Foot Calculation

To determine the oil-feet for each saturation category at an evaluation hole, three stages of calculations were completed. Firstly, the thickness of each uniformally saturated interval of oil sand that qualified for the saturation category was multiplied by its measured or estimated weight saturation. Then, the products of thickness and saturation, calculated for each interval, were added together to obtain a total value for the hole. Finally, the total value was multiplied by the appropriate weight to volume conversion factor to determine the thickness of the oil-feet existing at the hole being considered.

(iv) Recovery Factors

For the purpose of this report, the Board has employed the following recovery factors to convert the estimates of reserves in place to recoverable reserves:

ESTIMATED RECOVERY FACTORS
(expressed as a percentage of the oil-sand oil in place(1)

Range of Overburden Thickness - Feet -	Recovery of Raw Oil-Sand Oil (generally between 9 and 13° API at 60° F) - Per Cent -	Recovery of Up-graded Synthetic Crude Oil (30 to 37° API at 60° F) - Per Cent -
0 - 100	85	60
100 - 250	70	50
250 and greater	55	40

(1) based on the Oil and Gas Conservation Board cut-off of two per cent oil saturation by weight.

An explanation of these factors and their derivation is provided below:

Recovery of Raw Oil-Sand Oil

The recovery factors listed in the centre column indicate the percentage of the rich, intermediate and lean oil sands reserves in the ground that the Board considers, for the purpose of this report, to be recoverable at the surface in the form of raw and unaltered oil.

In selecting the raw oil recovery factor applicable to the 0 to 100 - foot overburden category, the Board considered the separate evidence submitted by Great Canadian Oils Sands Limited and the Cities Service Athabasca group to the Board at public hearings held during 1960 and 1962.[4] Both applications pertained to mining and plant processing schemes and they applied to reserves of the Athabasca deposit that, for the most part, occur beneath 0 to 100 feet of overburden.

In chosing the raw oil recovery factor for the oil sands that are buried by more than 250 feet of overburden, the Board considered evidence submitted during 1963 by the Shell Oil Company of Canada Ltd. with reference to its application to the Board to recover oil-sands oil by injecting steam and/or hot aqueous solutions into the oil

sands. The oil sands involved in this application belong to the Athabasca deposit and are covered by between 500 and 1400 feet of overburden. According to the evidence presented, the company anticipates a recovery efficiency of at least 50 per cent and possibly as high as 70 per cent of the oil in place in the clean McMurray sands.(5) These expected recovery efficiencies are, according to the applicant, based on laboratory research, theoretical work and field experiments. The values quoted by the company are with reference to the oil sands having a weight saturation greater than about six per cent whereas the corresponding Board's figure is with reference to the oil sands having a weight saturation greater than two per cent.

The recovery factor of 70 per cent shown in the table for the 100 to 250 - foot overburden category represents an arithmetical mean between the factors employed for the thinner and thicker overburden categories and is based on the assumption that these reserves will be recovered in part by mining and in part by in situ processes.

Recovery of Upgraded Synthetic Crude Oil

The recovery factors listed in the right column of the table represent the approximate percentages of the rich, intermediate and lean oil sands reserves in the ground that, in the opinion

of the Board, may be expected to be produced in the form of upgraded synthetic crude oil.

The Board has observed that, for the schemes involved in the various oil sands applications, the fuel, transportation and general processing losses experienced in upgrading the raw oil to synthetic crude oil were found or estimated to account for a total loss of about 30 per cent of the recovered raw oil. The Board has assumed that this value represents a reasonable average factor for the entire oil sands reserves. On this basis, the recovery factors shown in the right column were obtained by multiplying the raw oil recovery factors of the centre column by 70 per cent and rounding the product to the nearest even multiple of five.

3. Tabulation of Reserves

The Board has estimated that the oil sands of northern Alberta contain over 700 billion* barrels of oil in place. Of this total, over 400 billion barrels are considered as recoverable raw oil-sand oil from which about 300 billion barrels of upgraded synthetic crude oil are expected to be produced. It is obvious that this reserve is enormous for, by comparison, only 18.4 billion barrels of conventional oil, in place, or 5.1 billion barrels of conventional recoverable oil has been found to date in the Province.[(6)]

* one billion equals one thousand million

The reserve estimates are listed below and on the following pages in accordance with the system of classification employed for this study. The reserve figures are presented in terms of billions of barrels and they have been rounded to the nearest tenth of a billion barrels.

(A) TOTAL EVALUATED OIL SANDS RESERVES - CLASSIFIED BY STRATIGRAPHIC UNIT

	Reserves in Place, Billions of Barrels	Recoverable Reserves of Raw Oil-Sands Oil, Billions of Barrels	Recoverable Reserves of Upgraded Synthetic Crude Oil Billions of Barrels
Athabasca deposit (Wabiskaw-McMurray unit)....	625.9	369.1	266.9
Bluesky-Gething deposits....	51.5	28.3	20.6
Grand Rapids deposits.......	33.4	18.4	13.4
Total Evaluated Oil Sands...	710.8	415.8	300.9

(B) TOTAL EVALUATED OIL SANDS RESERVES OF ALL DEPOSITS - CLASSIFIED BY OVERBURDEN AND DRILLING DEFINITION

Overburden (Feet)	Reserves in Place Billions of Barrels			Recoverable Reserves of Raw Oil-Sands Oil, Billions of Barrels			Recoverable Reserves of Upgraded Synthetic Crude Oil Billions of Barrels		
	Drilled	Undrilled	Total	Drilled	Undrilled	Total	Drilled	Undrilled	Total
0-50	10.2	2.2	12.4	8.6	1.9	10.5	6.1	1.3	7.4
50-100	25.6	7.1	32.7	21.8	6.0	27.8	15.4	4.2	19.6
100-250	39.4	36.1	75.5	27.5	25.3	52.8	19.7	18.1	37.8
250-500	27.0	65.4	92.4	14.9	36.0	50.9	10.8	26.2	37.0
500-1000	30.0	206.8	236.8	16.5	113.7	130.2	12.0	82.7	94.7
1000-1500	14.8	160.4	175.2	8.2	88.2	96.4	6.0	64.1	70.1
1500-2000	4.1	47.1	51.2	2.3	25.9	28.2	1.6	18.9	20.5
2000-2500	3.1	31.5	34.6	1.7	17.3	19.0	1.2	12.6	13.8
Totals	154.2	556.6	710.8	101.5	314.3	415.8	72.8	228.1	300.9

(c) EVALUATED RESERVES OF THE ATHABASCA DEPOSIT - CLASSIFIED BY OVERBURDEN, OIL SATURATION AND DRILLING DEFINITION

(1) COMBINED CLASSIFICATION

0-50' OVERBURDEN	RESERVES IN PLACE, BILLIONS OF BARRELS	RECOVERABLE RESERVES OF RAW OIL-SANDS OIL, BILLIONS OF BARRELS	RECOVERABLE RESERVES OF UPGRADED SYNTHETIC CRUDE OIL BILLIONS OF BARRELS
RICH SANDS			
DRILLED............	7.1	6.0	4.3
UNDRILLED..........	1.6	1.4	1.0
TOTAL................	8.7	7.4	5.3
INTERMEDIATE SANDS			
DRILLED............	2.4	2.0	1.4
UNDRILLED..........	0.5	0.4	0.2
TOTAL................	2.9	2.4	1.6
LEAN SANDS			
DRILLED............	0.7	0.6	0.4
UNDRILLED..........	0.1	0.1	0.1
TOTAL.....	0.8	0.7	0.5
TOTAL, RICH, INTERMEDIATE AND LEAN SANDS, BENEATH 0-50' OF OVERBURDEN....	12.4	10.5	7.4
50-100' OVERBURDEN			
RICH SANDS			
DRILLED.............	18.4	15.7	11.1
UNDRILLED...........	5.1	4.3	3.0
TOTAL..................	23.5	20.0	14.1
INTERMEDIATE SANDS			
DRILLED.............	5.7	4.8	3.4
UNDRILLED...........	1.6	1.3	0.9
TOTAL......	7.3	6.1	4.3
LEAN SANDS			
DRILLED..............	1.5	1.3	0.9
UNDRILLED............	0.4	0.4	0.3
TOTAL..................	1.9	1.7	1.2
TOTAL, RICH, INTERMEDIATE AND LEAN SANDS BENEATH 50-100' OF OVERBURDEN....	32.7	27.8	19.6

100-250' Overburden	Reserves in Place, Billions of Barrels	Recoverable Reserves of Raw Oil-Sands Oil, Billions of Barrels	Recoverable Reserves of Upgraded Synthetic Crude Oil, Billions of Barrels
Rich Sands			
Drilled...............	29.0	20.2	14.5
Undrilled.............	26.5	18.6	13.3
Total.................	55.5	38.8	27.8
Intermediate Sands			
Drilled...............	8.2	5.7	4.1
Undrilled.............	7.6	5.3	3.8
Total.................	15.8	11.0	7.9
Lean Sands			
Drilled...............	2.2	1.6	1.1
Undrilled.............	2.0	1.4	1.0
Total.................	4.2	3.0	2.1
Total, Rich, Intermediate and Lean Sands Beneath 100-250' of Overburden...	75.5	52.8	37.8
250-500' Overburden			
Rich Sands			
Drilled...............	18.2	10.0	7.3
Undrilled.............	41.4	22.8	16.6
Total.................	59.6	32.8	23.8
Intermediate Sands			
Drilled...............	6.9	3.8	2.8
Undrilled.............	16.2	8.9	6.5
Total.................	23.1	12.7	9.3
Lean Sands			
Drilled...............	1.9	1.0	0.8
Undrilled.............	4.3	2.4	1.7
Total.................	6.2	3.4	2.5
Total, Rich, Intermediate and Lean Sands Beneath 250-500' of Overburden....	88.9	48.9	35.6

500-1000' Overburden	Reserves in Place, Billions of Barrels	Recoverable Reserves of Raw Oil-Sands Oil, Billions of Barrels	Recoverable Reserves of Upgraded Synthetic Crude Oil, Billions of Barrels
Rich Sands			
Drilled................	20.2	11.1	8.1
Undrilled..............	126.0	69.3	50.4
Total....................	146.2	80.4	58.5
Intermediate Sands			
Drilled................	6.4	3.5	2.5
Undrilled..............	43.5	23.9	17.4
Total....................	49.9	27.4	19.9
Lean Sands			
Drilled................	1.7	0.9	0.7
Undrilled........	11.7	6.5	4.7
Total....................	13.4	7.4	5.4
Total, Rich, Intermediate and Lean Sands Beneath 500-1000' of Overburden...	209.5	115.2	83.8
1000-1500' Overburden			
Rich Sands			
Drilled................	10.3	5.7	4.1
Undrilled............ ..	114.3	62.8	45.7
Total....................	124.6	68.5	49.8
Intermediate Sands			
Drilled................	3.1	1.7	1.3
Undrilled...	33.9	18.7	13.5
Total....................	37.0	20.4	14.8
Lean Sands			
Drilled................	0.9	0.5	0.4
Undrilled..............	9.1	5.0	3.6
Total....................	10.0	5.5	4.0
Total, Rich, Intermediate and Lean Sands Beneath 1000-1500' of Overburden....	171.6	94.4	68.6

1500-2000' Overburden	Reserves in Place, Billions of Barrels	Recoverable Reserves of Raw Oil-Sands Oil, Billions of Barrels	Recoverable Reserves of Up-graded Synthetic Crude Oil, Billions of Barrels
Rich Sands			
Drilled................	2.3	1.3	0.9
Undrilled....	20.5	11.3	8.2
Total..................	22.8	12.6	9.1
Intermediate Sands			
Drilled................	0.3	0.1	0.1
Undrilled......	9.6	5.3	3.9
Total..................	9.9	5.4	4.0
Lean Sands			
Drilled................	0.1	*	*
Undrilled..............	2.6	1.5	1.1
Total..................	2.7	1.5	1.1
Total, Rich, Intermediate and Lean Sands Beneath 1500-2000' of Overburden...	35.4	19.5	14.2

* Negligible (less than 50 million)

(11) Evaluated Reserves of the Athabasca Deposit - Classified by Oil Saturation Only

Category	Reserves in Place, Billions of Barrels	Recoverable Reserves of Raw Oil-Sands Oil, Billions of Barrels	Recoverable Reserves of Up-graded Synthetic Crude Oil, Billions of Barrels
Rich Sands			
(greater than 10% weight saturation).......	440.8	260.5	188.3
Intermediate Sands			
(5 to 10% weight saturation).......	145.7	85.5	61.9
Lean Sands			
(2 to 5% weight saturation).......	39.4	23.1	16.7
Total			
(greater than 2% weight saturation).......	625.9	369.1	266.9

(iii) Evaluated Reserves of the Athabasca Deposit - Classified by Drilling Definition Only

	Reserves in Place, Billions of Barrels	Recoverable Reserves of Raw Oil-Sands Oil, Billions of Barrels	Recoverable Reserves of Upgraded Synthetic Crude Oil, Billions of Barrels
Drilled	147.5	97.8	70.1
Undrilled	478.4	271.3	196.8
Total	625.9	369.1	266.9

(d) Evaluated Reserves of the Bluesky-Gething Unit - Classified by Deposit, Overburden and Drilling Definition

Deposit and Overburden	Reserves in Place, Billions of Barrels			Recoverable Reserves of Raw Oil-Sands Oil, Billions of Barrels			Recoverable Reserves of Upgraded Synthetic Crude Oil, Billions of Barrels		
	Drilled	Undrilled	Total	Drilled	Undrilled	Total	Drilled	Undrilled	Total
Peace River									
1000-1500'	0.1	0.2	0.3	0.1	0.2	0.2	0.1	0.1	0.1
1500-2000'	1.3	14.3	15.6	0.7	7.8	8.5	0.5	5.7	6.2
2000-2500' **	3.0	31.5	34.5	1.6	17.3	19.0	1.2	12.6	13.8
Total	4.4	46.0	50.4	2.4	25.3	27.7	1.8	18.4	20.1
Buffalo Head Hills									
500-1000'	*	0.1	0.1	*	0.1	0.1	*	*	0.1
1000-1500'	0.1	0.5	0.6	0.1	0.2	0.3	*	0.2	0.2
1500-2000'	*	0.1	0.1	*	0.1	0.1	*	0.1	0.1
2000-2500'	*	*	0.1	*	*	*	*	*	*
Total	0.2	0.7	0.9	0.1	0.4	0.5	0.1	0.3	0.4
Loon River									
1000-1500'	*	*	*	*	*	*	*	*	*
1500-2000'	*	*	0.1	*	*	*	*	*	*
Total	0.1	*	0.1	0.1	*	0.1	*	*	*
Total, Bluesky-Gething Deposits	4.7	46.8	51.5	2.6	25.7	28.3	1.9	18.7	20.6

* Negligible (less than 50 million)

** Includes the minor reserve contained beneath the overburden thicker than 2500'.

(E) Evaluated Reserves of the Grand Rapids Formation - Classified by Deposit, Overburden and Drilling Definition

Deposit and Overburden	Reserves in Place, Billions of Barrels			Recoverable Reserves of Raw Oil-Sands Oil, Billions of Barrels			Recoverable Reserves of Upgraded Synthetic Crude Oil, Billions of Barrels		
	Drilled	Undrilled	Total	Drilled	Undrilled	Total	Drilled	Undrilled	Total
Wabasca									
250-500'	0.1	3.5	3.5	0.1	1.9	1.9	*	1.4	1.4
500-1000'	1.4	24.6	26.0	0.8	13.5	14.3	0.6	9.8	10.4
1000-1500'	*	0.8	0.9	*	0.5	0.5	*	0.3	0.4
Total	1.6	28.9	30.4	0.9	15.9	16.7	0.6	11.5	12.2
Pelican									
500-1000'	Negligible - included with values below								
1000-1500'	0.3	1.5	1.8	0.1	0.8	1.0	0.1	0.6	0.7
Total	0.3	1.5	1.8	0.1	0.8	1.0	0.1	0.6	0.7
Sand Rapids									
500-1000'	0.1	1.0	1.1	0.1	0.5	0.6	0.1	0.4	0.4
1000-1500'	—	Negligible - included with above values					—	—	—
Total	0.1	1.0	1.1	0.1	0.5	0.6	0.1	0.4	0.4
Total, Grand Rapids Deposits	2.0	31.4	33.3	1.1	17.2	18.3	0.8	12.5	13.3

* Negligible (less than 50 million)

4. Reliability of the Estimates

This discussion, pertaining to the reliability of the foregoing reserve estimates, is divided into two parts. The first part contains reference to the fallible aspects of the evaluation methods and the second section contains reference to the accuracy and finality of the reserve estimates.

(a) Fallible Aspects of the Evaluation Methods

Where possible, reliable data and evaluation procedures were used to estimate the oil sands reserves. However, for

certain parts of the reserves, it was necessary to use less reliable data and to take the more fallible approaches described below.

(i) Over much of the undrilled reserve areas, distances of many miles exist between adjacent wells or evaluation holes. In preparing the reserve maps, the Board had no alternative but to connect, by isopachs, the values derived at the widely-spaced wells or holes. This was done with some reservation because, in certain areas near the Athabasca River where closely spaced holes exist, considerable variations in oil feet were noted over distances of only one mile or less. Although the oil content is expected to be more uniform in other parts of the Athabasca deposit and in the Bluesky-Gething and Grand Rapids deposits, the Board recognizes that the reserves contained between widely-spaced holes or wells could warrant considerable revision when additional drilling is undertaken.

(ii) For certain uncored holes of the Athabasca deposit, the core analysis-log relationship established at nearby cored holes obviously did not apply. In such instances, arbitrary positions had to be employed for the lines used to distinguish between the rich and intermediate oil saturation categories and the barren intervals on the log. The oil-foot

calculations were considerably influenced by this arbitrary decision and, therefore, they are subject to error.

(iii) To estimate the reserves of the lean oil sands of the Athabasca deposit, the Board first established from 480 core analyses the ratio of lean oil sands pay to intermediate oil sands pay and then multiplied this ratio by the reserves of the intermediate oil sands that had been estimated from reserve maps. The reserves based on this short-cut method are subject to some error because the distribution pattern of the lean oil sands is not necessarily identical to that of the intermediate oil sands throughout the deposit.

(iv) The resistivity log characteristics of certain chalky and/or coaly sandstones of the Bluesky-Gething unit and certain fresh water-bearing, highly cemented and/or conglomeratic sandstones of the Grand Rapids formation are similar to the resistivity log characteristics of oil sand. Due to this resemblance, some barren intervals may have been inadvertently interpreted as oil sand at certain wells for which porosity logs were not available.

(v) Some of the oil sand pay recognized for estimating the reserves of the Bluesky-Gething and Grand Rapids deposits may have contained gilsonite rather than the

normal type of oil-sands oil. However, where gilsonite was seen in the cuttings, the section was excluded from the reserve estimates.

(vi) When relatively light oil staining was observed in the sample cuttings, the Board assumed that the sand was only partly saturated and applied a low saturation factor to the sand. In reality, the sand may have been completely saturated and the appearance of the light oil staining may have been caused by the washing of the cuttings or by the existence of a lighter gravity oil at the area being evaluated.

(vii) All saturation factors used for the Bluesky-Gething and Grand Rapids deposits were estimated from the appearance of the sample cuttings. Although the estimates are believed to be somewhat conservative, the fact that the method is qualitative rather than quantitative could mean that the estimates made for at least some of the wells are in considerable error.

(b) Accuracy and Finality of the Reserve Estimates

The Board believes that its estimate of the total oil sands reserves for the combined deposits is in reasonable agreement with the actual reserves in existence within the areas evaluated. However, it believes that a considerable amount of additional evaluation drilling is needed to establish, with confidence, the magnitude of the reserves within certain widespread portions of the area classified

as undrilled in this report. Such drilling would not only permit a more accurate estimate of the total oil sands reserves but it would enable a more reliable geographic identification of the undrilled reserves which constitute almost 80 per cent of the reserves of the Athabasca deposit and over 90 per cent of the reserves of the other deposits.

The Board expects that additional oil sands reserves will be delineated when evaluation drilling is conducted beyond the areas evaluated for the purpose of this report. The possibility of such a reserve growth is particularly applicable to the Bluesky-Gething and Grand Rapids deposits.

REFERENCES

(1) M.A. Carrigy, "Geology of the McMurray Formation, Part III, General Geology of the McMurray Area", Research Council of Alberta, Geological Division Memoir 1, 1959.

(2) Shell Oil Company of Canada Ltd., Exhibit 1, Hearing 220, Sept. 6, 1962, pages III-2 and III-3; on file at the Oil and Gas Conservation Board.

(3) M.A. Carrigy, "Effect of Texture on the Distribution of Oil in the Athabasca Oil Sands, Alberta, Canada", Journal of Sedimentary Petrology, June, 1962.

(4) Great Canadian Oil Sands Limited, "Summary Report", 1960 Hearing No. 167, Exhibit 1, on file at the Oil and Gas Conservation Board, Calgary, and
Cities Service Athabasca group, Exhibit No. 1, Hearing No. 219, 1962, on file at the Oil and Gas Conservation Board, Calgary.

(5) Shell Oil Company of Canada Limited, Exhibit 1, Hearing 220, Sept. 6, 1962, page III-5, on file at the Oil and Gas Conservation Board.

(6) Oil and Gas Conservation Board, "Reserves of the Province of Alberta as of December 31, 1962", on sale at the Oil and Gas Conservation Board, Calgary.